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MEAT HYGIENE

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FOOD AND AGRICULTURE ORGANIZATION
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INTRODUCTION

The purpose of this monograph is to bring together the latest experience in the safe processing of meat from producer to consumer. While much of the monograph comprises the contributions and discussions at a WHO/FAO Seminar on Meat Hygiene held in Copenhagen in February 1954, it is not intended as a record of that meeting. The original contributions have, where necessary, been expanded or brought up to date ; several new articles have been contributed ; appropriate illustrations have been widely sought ; and much detail—on laboratory techniques for the detection of meat-borne diseases, and on current practice in meat processing in various countries—has been incorporated in annexes. In its present form, this material should give a fairly rounded picture of the public-health aspects of the processes involved in the preparation, inspection, and marketing of meat and its products.

Since meat is a perishable commodity and its poor handling daily exacts a large public-health and economic toll, there can be no room for complacency over problems of meat hygiene, either in under-developed or in advanced countries. Nations can ill afford the disruption of activities in the home and community caused by meat-borne diseases, not to mention the formidable economic wastage and nutritional losses to the population of two fundamental needs—protein and fat.

The primary purpose of good meat-hygiene practice is, of course, to prevent transmission of disease to man and to provide a safe, wholesome product for his consumption. Thus, meat hygiene is essentially a public-health function. The secondary aims, lying rather in the economic sphere, include reduction of losses in meat and its by-products and prevention of disease transmission to other domestic animals. These are matters of concern chiefly to trade, food, and agricultural authorities.

In many countries the division of responsibility for meat-hygiene supervision among government departments is not clear-cut. Although no standard or uniform pattern exists, it is readily apparent that the effective operation of a meat-hygiene service must be based on close working relationships between the triad of medical, veterinary, and sanitary-engineering disciplines. Since meat hygiene is essentially a public-health function, and the veterinarian

is usually best trained and equipped to deal with diseases transmissible through meat, some health authorities have found it advantageous to include a veterinary public-health branch in their services, to cover meat-hygiene needs as well as other responsibilities such as zoonoses. A closer co-ordination of the activities and interests of groups concerned with meat hygiene has thus been achieved.

This monograph is not intended to serve as a guide or to train those responsible for supervising the soundness of meat from the producer to the consumer ; texts of this nature are already available—for example, Die Ausführung der tierärztlichen Fleischuntersuchung, *by F. Schönberg and O. Zietzschmann, H. Thornton's* Textbook of meat inspection, *and A. R. Miller's* Meat hygiene. *Its aim is, rather, to illuminate recent advances and problems in diverse aspects of this wide subject for the benefit of the responsible authorities in public health and in veterinary science.*

Part I

EPIDEMIOLOGY

THE EPIDEMIOLOGY OF MEAT-BORNE DISEASES

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INTRODUCTION

Since the dawn of history, man has had to match his wits against two-, four-, and six-legged adversaries in a struggle for existence. Once upon a time, when he won these contests, he ate as much of his opponent as he could stomach. Perhaps in those days, as Hippocrates contended, " men often suffered terribly from their indigestible and animal-like diet, eating raw and uncooked food ... They suffered as men would suffer now from such a diet, being liable to violent pain and sickness and a speedy death ..." [24] With the development of agriculture and animal husbandry, mankind began to depend increasingly for strength and sinew upon the cooked flesh of tamed herbivores. Societies which could not or would not farm, such as the present Eskimo, the Central African, or the Australian aboriginal, sought their muscle-building provender among fish and marine mammals, game, and wild birds. When hunger was acute enough, the occasional foray would be launched against more dangerous beasts, e.g., the polar bear, the lion, and the crocodile.

Although human and insect predators have long outvied the quadrupeds as hazards to man's survival, they are seldom eaten, for cannibalism is generally frowned upon, while locusts and wild honey never did furnish a fashionable diet. Most of the animal kingdom is now at our mercy, and hence we can often indulge our carnivorous impulses at the expense of the vanquished, with varying degrees of refinement and satiety. These impulses sometimes remain individualized but highly transmuted, as in those cunningly disguised beasts of prey, the trout or tuna fisherman, and the duck or elephant hunter—whose trips into the wilds are seldom motivated by hunger—or they may be channelled into the crudely purposeful activities of the modern abattoir and meat-packing plant.

Present-day urban civilization is characterized by an intricate network of arrangements for producing, slaughtering, processing, distributing, storing, and preparing for consumption, the flesh and viscera of certain domesticated mammals and birds, notably the cow, pig, sheep, and chicken. In many countries, the horse, buffalo, goat, and rabbit, as well as the turkey, duck, and goose, also provide substantial amounts of animal protein ; while some areas of the globe are forced to depend mainly on feral sources, such as seal, moose, bear, deer, reindeer, and wildfowl, for their meat supplies. (Of course, to some degree all over the world, the rivers, lakes, and oceans yield important supplements ; but for the purposes of this paper neither fish nor marine products such as winkles and whales are being considered as " meat ".)

Meat is not an essential food—vegetarians often seem to thrive—but is a tasty, easily digested, and highly efficient source of the multifarious proteins of the animal body, from inert horn and flimsy silk to the vital enzymes which make possible the noblest human thoughts and actions. When essential proteins are not replenished by the diet, some form of malnutrition eventually becomes manifest, as in the extreme emaciation or the hunger oedema of prisoner-of-war camps in Europe and the Far East, and the peculiar " kwashiorkor " (red-boy) syndrome in dark-skinned Africans. Low levels of serum protein may also predispose to infection, by hindering the production of immune globulins. Moreover, certain animal viscera, especially the liver, serve as important sources of vitamins A and B_{12}. Crow's liver was an ancient Chinese remedy for anaemia ; and roasted ox liver was advocated for eye diseases in the Ebers papyrus, an Egyptian medical treatise dating from about 1600 B.C. In parts of fourteenth century Europe, goat liver was known as a cure for night blindness ; while the Newfoundland fisherman's liability to nyctalopia, after overlong subsistence on a diet of unleavened bread and fish, has traditionally been controlled by occasional resort to cooked cod's liver.[53] Again, the Eskimoes of King William Island, who cannot satisfy their vitamin A needs with green vegetables and dairy produce, feast ritualistically on raw seal liver.

Apart from certain rather far-fetched examples (*vide infra*), and a few notorious historical instances of gluttony bringing dire deserts (as in the death of King Henry I of England allegedly from a surfeit of lampreys), heavy meat consumption *per se* appears to bring no ill effects. For instance, some of the nomadic Tartars of central Europe were almost exclusively meat eaters during their conquering heyday in the sixteenth and seventeenth centuries, and yet were renowned for longevity. Nowadays, the Masai tribe of East Africa, the gauchos of certain South American countries, and of course the Eskimoes, consistently eat very large amounts of meat with impunity. Again, the wealthier classes in England from mediaeval

to Victorian times resembled present North Americans in their carnivorous propensities. However, the gout and the stone of a former era, and the modern tendency to hypertension, are incorrectly ascribed to excessive meat consumption.

The wide range in annual meat consumption shown by certain European countries and Canada and the USA (see Annex 1, page 369) mainly expresses local custom, the prevailing level of prosperity (the "standard of living"), and differing regional ratios of human to domestic herbivore populations. Some of these countries might beneficially raise their consumption; others could easily eat and waste less meat without loss of health and happiness. Had similar data been available from other parts of the world, the lower limits of the range would have extended below the level consistent with full health and vigour. In so far as this maldistribution of the world's meat supplies be remediable, its ultimate rectification is of concern to humanitarians everywhere. Merely to discuss the economic problems involved, however, would be a task quite beyond the scope of this paper. Our purpose is to assist in the dissemination of authoritative knowledge of meat hygiene, so that supplies of this costly and perishable foodstuff may be conserved, and shall not carry disease to the consumer.

Historical Development of Meat Control Measures

Meat hygiene began with the earliest civilizations of the Mediterranean area. For instance, the food edicts of ancient Egypt proclaimed the pig unclean and the cow sacred, and banned their flesh as food for man. The butchering of the ox, goose, and kid—the staple meats—and likewise of the ibex, gazelle, and oryx, which were also in demand, was governed by quite elaborate rules, many of them linked to religious taboos and rituals as much as to sanitation. The Israelites adopted these edicts about 2000 B.C., with certain extensions such as the prohibition of the Egyptian custom of collecting, for cooking purposes, the blood of a slaughtered animal. The Mosaic food laws * are still faithfully observed by orthodox Jews, and also—with some modifications—by strict Mohammedans.

Several of the classical Greek and Roman writers, such as Hippocrates, Aristotle, and Virgil, noted the similarity of disease processes in man and animals; but in the Middle Ages any speculations about their possible relationship would have been frowned upon by the Church. In the intellectual climate then prevailing, as Meyer has suggested,[141] "Man, an image of God, could and should not be compared with representatives of the animal kingdom".[141] Small wonder that in mediaeval Europe,

* Leviticus, 11; Deuteronomy, 14

meat inspection was sporadic, cursory, and carried out against heavy odds. Nevertheless, it was practised in France as early as 1162, while in what is now Germany, special inspectors of pigs were appointed at Aachen in 1385, and a citizen of Regensburg was imprisoned in 1434 for attempting to sell " measly " pigs in which the cysts had been punctured. In 1615, in Bavaria, the slaughter and sale of calves under 3 weeks of age was prohibited, and ante-mortem and post-mortem inspection was established.

In England, early civic records indicate that one of the duties of the mayor and his officers in the larger cities was to oversee the flesh markets. For example, in 1319, the wardens of the City of London condemned two carcasses of beef seized as being " putrid and poisonous ". The would-be purveyor was convicted by a jury of attempting to sell " bodies that have died of disease ". He was pilloried, and the offending carcasses were burnt under his nose.[53] The Urban Sanitary Act of 1388, passed by the Parliament of King Richard II, deplored that

" so much Dung and Filth of the Garbage and Intrails as well of beasts killed, as of other Corruptions, be cast and put in Ditches, Rivers, and other Waters, and also within many other Places, within, about and nigh unto divers Cities, Boroughs, and Towns of the Realm, and the suburbs of them, that the air there is greatly corrupt and infest, and many Maladies and other intolerable Diseases do daily happen, as well to the Inhabitants ... as to others repairing and travelling thither ... "

These annoyances had to be utterly removed and avoided forthwith, under pain of a heavy fine.[35] Regulations dating from the fourteenth and fifteenth centuries forbade the use of tainted meat in the public cook-shops, which were established already by the twelfth century along the bank of the River Thames. In these cookshops, according to Drummond & Wilbraham,[53]

" partly because of the difficulty of keeping meat fresh, but also because only the larger houses had adequate means for cooking . . . a wide selection of pies, puddings and baked meats was prepared ".

In such circumstances, it might be expected that the temptation to use tainted meat would match the difficulty of detecting the transgressor. Similar hazards faced the predominantly meat-eating population of England in the seventeenth and eighteenth centuries, when up to 100 000 head of cattle were driven slowly by road each year to the London markets.

The present law in England and Wales governing the hygienic manufacture, storage, and wholesomeness of meat products is based on the Food and Drugs Act of 1938. The regulatory powers vested in the appropriate authorities by this Act appear adequate ; yet, despite the lapse of four and a half centuries since the promulgation of the first Sanitary Act,

the great majority of food poisoning episodes reported in recent years to the Ministry of Health have been caused by manufactured meat products.

In North America, although stockyards, slaughterhouses, and meat-packing plants now operate on a huge scale under the scrutiny of government-employed veterinarians and sanitarians, this is a comparatively recent development. Only rudimentary meat inspection was carried out in a few cities of the USA before 1884, when the Federal Bureau of Animal Industry was formed. Seven years later a meat inspection department was created within this bureau, and inspection of meat destined for human consumption was made compulsory, but the law remained rather ineffective, until the Federal Meat Inspection Service was re-established under the Food and Drugs Act of 1906. Although by 1949 Federal officials were inspecting meat in no fewer than 996 plants in 347 cities and towns,[182] unfortunately about one third of all animals slaughtered for food in the USA were not thus inspected. Moreover, a good deal of small-scale slaughtering and processing still occurs in areas without provision for any kind of meat inspection.

In Canada, there is a clear history of two centuries of meat hygiene legislation. For in 1707, exactly 100 years before Napoleon was enlightened enough to found the public abattoir system in Paris, the first public health laws were passed in New France, in order to procure the sale of only good-quality meat.

> " No butcher under pain of confiscation and fine could kill an animal without informing the King's Officer appointed for the purpose ... and bringing him to the place to ascertain if the animal was in a healthy enough state for public distribution of the meat. No inhabitant of the country could bring and sell meat in the town without presenting to the King's Officer or his representative a certificate from a judge ... the seigneur, or curé, or military officer, which certificate should state that the animals brought by them were not suffering from disease of any kind before being killed ... " [97]

Heagerty rightly comments : " These laws compare favourably with modern ones." Compulsory meat inspection was instituted in Canada in 1907, where today relatively little meat is sold which has not been subject to inspection by representatives of Federal, Provincial, or Municipal Departments of Agriculture or Health.

Recognition of Meat as a Disease-conveying Agent

Throughout human history, meat has been a commodity both greatly desired and somewhat feared. The slow evolution of slaughtering rituals and inspection regulations points to early recognition of some of the dangers inherent in the consumption of meat abnormal to the eye and

nose. The inadequacy of these criteria as safeguards is, of course, still too little realized.

Aristotle's claim that many animals did not grow from kindred stock, but might develop in the fur or excrement of other animals, was based on naked-eye observation and faulty deduction. Similarly derived were the Roman scholar Varro's revival of an ancient belief that bees are born in the decayed flesh of bulls and the story of Samson the Israelite's discovery of a swarm of bees, and honey, in the body of a young lion he had rent a while before.[a] The weight of such authorities supported ancient beliefs of this kind for about 2000 years, until they were first discredited by experiments reported in 1668 by Redi, who found that no fly maggots developed in wide-mouthed vessels covered with fine gauze and containing meat or fish, whereas the flesh rapidly teemed with maggots in a group of similar vessels left open to flies. But the myths of heterogenesis, necrogenesis, and spontaneous generation persisted or were revived in various guises for another two centuries, causing many bitter disputes —in the mid-eighteenth century between Needham, the Welsh priest, and Spallanzani, the Italian naturalist; in the early nineteenth century between the two German scientists, von Liebig and Schwann; and finally, in the second half of that century, between the English neurologist-dialectician Bastian and the French bacteriologist Pasteur.[19]

Ultimately, these and ancillary controversies led to the important conclusions that closely related genera of invisible agents were responsible for such varied but age-old phenomena as the wine bubbling, the dough rising, the meat rotting, the wound suppurating, and the man or animal sickening of a fever, and sometimes dying. Also, by then it had become evident that meat favoured the multiplication of many kinds of micro-organisms reaching it from various sources besides the atmosphere, and that these microbes could be killed by certain physical and chemical agencies. In the comparatively brief period since inauguration of the Pasteurian era, our understanding and control of these phenomena has been greatly extended. There is no longer any justification for merely traditional methods and empirical regulations for the slaughter, inspection, handling, and distribution of meat.

In the light of current knowledge, the basic purposes of meat hygiene appear to be averting spoilage and preventing meat-borne infection, by reducing to a minimum the opportunities for micro-organisms, particularly the pathogens, to gain access to meat and to proliferate therein. Likewise, the epidemiology of meat-borne diseases is mainly concerned with the nature, sources, and modes of spread and growth of these organisms,

[a] Judges, 14. 8

and with the conditions inimical or conducive to their survival, considered in relation to meat at all stages from live animal to consumer's table. In approaching this subject, Hirsch's [102] definition of epidemiology as :

> " a science which will give, firstly, a picture of the occurrence, the distribution, and the types of the diseases of mankind in distinct epochs of time and at various points of the earth's surface ; and, secondly, will render an account of the relations of these diseases to the external conditions surrounding the individual and determining his manner of life " [102]

has been borne in mind. In the limited compass of this paper, neither of these two definitions can be followed too completely, but it is hoped that their dual influence will be sensed.

Classification of Meat-borne Diseases

There would be little purpose in discussing here the terminology of food-borne infections and intoxications, the confused state of which has been deplored by many authors, including recently Meyer.[142] The following classification of meat-borne diseases is adopted because it provides a simple, logical *ad hoc* framework :

(1) meat-borne diseases of chemical or toxicological origin ;

(2) endogenous (intravital) animal infections transmissible to man by meat (zoonoses) ;

(3) infections and intoxications due to exogenous (human and environmental) contamination of meat and manufactured meat products (bacterial food poisoning).

This classification is bound to prove inadequate and inconsistent in certain respects, the more obvious of which will be pointed out in due course. Typical examples of conditions falling under these main headings will be considered epidemiologically, and present control measures will be critically reviewed in the light of the basic principles involved. This analysis cannot hope to be exhaustive and detailed, but a few rare diseases, or unusual modes of transmission of the commoner diseases, will be introduced here and there to give point or colour to the argument.

MEAT-BORNE DISEASES OF CHEMICAL OR TOXICOLOGICAL ORIGIN

"Intrinsic" Toxicity

Among the common mammalian or avian species whose flesh is liable to be eaten by man, none is intrinsically or seasonally poisonous; there is fortunately no parallel to the poisonous fish of the Caribbean and certain Pacific areas. In a fish-eating and densely-populated country such as Japan, tetradon poisoning (a special form of ichthyosarcotoxism) may claim hundreds of victims annually.[142] Again, there are no obvious analogues to the mysterious, but presumably fish-borne Haff disease (acute alimentary myositis) of the Baltic States,[11] or to the sporadic outbreaks, in widely-separated parts of the world, of paralytic shellfish poisoning.[142] The active principles in both tetradon and paralytic shellfish poisoning are alkaloids, which in the latter instance originate in certain species of Gonyaulax, a dinoflagellate plankton upon which mussels and clams may feed.

By contrast, even when livestock have died from eating poisonous plants, such as ergotized grain and Senecio, their flesh is unlikely to contain a sufficient concentration of alkaloids—unless eaten repeatedly and excessively—to cause detectable illness in the human consumer. Further, a cow with "trembles", due to grazing on white snakeroot or rayless goldenrod, may convey tremetol poisoning (the "milk sickness" of frontier days in North America) through her milk or milk products; but her flesh is seldom dangerous. In circumstances such as these, it is always wiser to play safe; and it should be borne in mind that even if alkaloids and other toxic substances seldom accumulate in high concentration in muscle tissues, this may not hold for certain viscera, especially the liver. That organ's elaborate and vital functions as a detoxifier and storehouse of specific biochemicals may sometimes render it poisonous in rather bizarre ways. For example, the Eskimoes traditionally regard the liver of the Arctic fox as poisonous, while explorers since Elizabethan times have recognized the toxicity of polar bear liver. The explanation for these aversions lies in the extremely high vitamin A content of such livers, which may induce in the consumer a hypervitaminosis syndrome closely resembling scurvy.[179, 180]

Toxic Chemicals of Telluric Origin

Organic and inorganic chemicals may gain access to meat from various sources, and may exert toxic effects when persistently consumed, even though present in very small amounts. Cereals and vegetables grown in

naturally seleniferous or fluorotic soils often show appreciable contents of selenium and fluorine compounds, which become distributed in the tissues of cattle and poultry fed upon them. Continued ingestion of minute quantities of these compounds may harm man or animals living in such areas;[68, 129] but the relatively low concentration of these elements in muscle renders meat unlikely to be a major source of chronic selenium or fluoride poisoning.

Toxic chemicals present in the soil need not be of geological origin, but may reach there, and make their way thence into animal tissues, from the increasing reliance of scientific agriculture upon artificial additives, which serve as fertilizers, soil conditioners, weed killers, insecticides, or rodenticides. Some of these substances are simple, well tried, and harmless; others, of complex structure and only partially understood mechanism, are known to be toxic to higher as well as to lower forms of life; while many have not been used long enough for their innocuity to be established.

Chemical Preservatives

Certain toxic chemicals may be added deliberately to meat as preservatives. These so-called "chemical preservatives" have been subject to controversy ever since Dr Harvey Wiley of the Bureau of Chemistry, United States Department of Agriculture, began his "pure food" crusade half a century ago. There would be little point in reviving here the many heated disputes which arose over such issues as the difficulty of reconciling legal and medical definitions of the very term "chemical preservative"; the evidence pertaining to the alleged injuriousness of these agents; the limits of tolerance permissible; and the extent and mechanisms of their inhibitory effects on food spoilage. For further details Tanner[203] may be consulted.

The substances chiefly concerned are salicylic, boric, and benzoic acids and their salts, and formaldehyde. Of these, the first to be indicted and banned, shortly after the United States Food and Drugs Act was passed in 1906, was formaldehyde;[218] yet it is present in wood smoke. On the other hand, boric acid is now recognized as one of the most toxic and least preservative of the agents mentioned; but it was permitted in sausages and potted meats in England, and could be dusted in large amounts over hams and bacon imported into that country, until 1927. In fact, during the food shortages resulting from the Second World War, the Ministry of Food in Great Britain rescinded the ban on the use of boron compounds in bacon and ham, without setting maximum limits. The presence of about 800 grains of borax (roughly equivalent to 7% of boric acid) per pound of sausage is reported to have caused rapid onset of abdominal

pain, with severe vomiting, in 30-40 soldiers at an Army camp in England.[54]

Sodium benzoate is the only chemical preservative which may now be added to meat products in the USA, and even this agent is not permitted in Canada. There is no clear-cut distinction between such a chemical and several other substances not generally classed as meat preservatives, for example, sodium and potassium nitrate and nitrite, acetic acid, numerous oils and spices, and sundry aldehydes and acids in wood smoke. Present definitions and arbitrary dividing lines seem due for adjustment, especially since advertising ingenuity and an aroused public interest in nutritional questions are creating pressures for the addition to foodstuffs of a new assortment of chemicals, including vitamin supplements, antibiotics as bacterial growth inhibitors, and glutamic acid to tenderize and evoke flavour.

Accidental or Criminal Contamination with Chemicals

Such metallic ions as lead, zinc, cadmium, or antimony are well known to exert injurious effects upon the human body when ingested. In various forms—for example, as alloy components, coatings, and glazes—these metals have been used at times in the manufacture of cooking or food-storage vessels, cans, or foil wrappings, and have rendered toxic the foodstuffs in contact with them. Monier-Williams[149] has stressed the dangers of plumbism which arise from plating cheaper-quality cooking utensils with tin containing small quantities of lead. He attributed the excessive amounts of lead found occasionally in corned beef to careless soldering of can seams. Galvanized or cadmium-plated receptacles, and cheap enamelware glazed with antimony compounds, are possible but unlikely sources of meat-borne chemical poisoning, since only very acid foods seem liable to be affected in this fashion.

Cleaning agents for dishes and silverware may be carelessly introduced into any foodstuff, including meat. A more serious possibility arises from the physical resemblance of sodium fluoride and arsenious oxide (both highly toxic substances) to common salt, sugar, starch, baking soda, cream of tartar, and flour. Sodium fluoride has been accidentally mistaken, at times with disastrous results, for every one of these common culinary ingredients, mainly owing to the foolish habit of keeping a package of roach powder adjacent to food supplies on kitchen shelves. Such powder, containing a high percentage of sodium fluoride, can also gain access to any exposed food through being sprinkled, or sprayed with a bellows, on to the floors of insect-infested bakeries, canteens, and restaurants.

Arsenic, a powerful rodenticide, may similarly find its way into food accidentally, but has also found favour, for many centuries, as a homicidal

agent. Although usually employed thus against individuals, arsenic has occasionally been involved in apparent attempts at mass murder. For example, in 1914, at a Chicago banquet held in honour of an archbishop, over 100 people were poisoned. Although the soup was found to contain large amounts of arsenic, the cook was never apprehended.[138]

A saboteur or homicidal maniac may resort to almost any toxic chemical. Only a few years ago, commercial caustic soda issued to plumbers for unplugging floor drains in a prison was apparently introduced maliciously into meat stock, thereby causing three successive outbreaks of acute gastroenteritis, each affecting 400-600 inmates. Soup and gravy prepared from the meat stock had a pH of over 13, and proved lethal when fed to mice.[210]

Control Measures

The main public-health safeguards against toxic chemicals in meat, whatever the route of access, must rest upon up-to-date and explicit regulations under the food and drugs acts of the various countries. Officials of the government bodies charged with administering these laws should recognize and make known the indispensability of stringent licensing, vigilant field work, and patient research. Moreover, since the deleterious effects of these substances on human health may be insidious and not necessarily reproducible in experimental animals, ready interchange of information and mutual understanding should be encouraged between practising physicians, public health workers, veterinarians, and representatives of the meat industry.

The accidental forms of chemical contamination can be best avoided by applying enlightened common-sense to the design and manufacture of utensils and equipment, and to the actual processing of meat and its products. Against felonious intent, the precautions to be taken will depend upon circumstances and the degree of anticipated risk.

ENDOGENOUS ANIMAL INFECTIONS TRANSMISSIBLE TO MAN BY MEAT (ZOONOSES)

Since ancient times, mankind has realized that his meat supplies could be imperilled by outbreaks of disease among wild and domestic animals. Virgil, for instance, noted the spread of anthrax among flocks of sheep. It took much longer for the fact to be accepted that human health and life could be endangered by the acquisition of specific diseases originating in the animal kingdom. Fracastoro seems to have realized, in the first

half of the sixteenth century, that rabies was conveyable to man by the bite of a dog; while Jenner, at the end of the eighteenth century, showed conclusively that cowpox could both infect and protect humans. Yet at the threshold of the twentieth century, Koch, the discoverer of the causal bacillus of human tuberculosis, denied the transmissibility of the bovine disease to man. Today we know that animals are subject to at least as many infections—viral, rickettsial, fungal, and helminthic—as man is heir to; and also, that in the many types and patterns of host-parasite relationships which have evolved over countless millenia, the hosts prove interchangeable surprisingly often. Moreover, in recent years, the problems involved in the epidemiology and control of these diseases have assumed previously unimagined complexities, since it is now clear that serious human infections can be acquired from animals which may be only mildly ill, or even apparently healthy.

Virchow applied the term "zoonoses" to primary infections of animals which are by any route conveyable to man. This section is concerned with those zoonoses, manifest or latent, which humans may acquire through the handling or ingestion of meat.

Zoonoses acquired Occasionally through the Intestinal Tract

Almost any zoonosis can be classified as potentially meat-borne, if the term "handling" be interpreted liberally enough. For in the course of capturing, slaughtering, skinning, dressing, or preparing animals for the table, many opportunities arise for infective agents to be transferred from them to man, through portals of entry other than the gastro-intestinal tract, such as the respiratory tract (by inhalation of droplets or dust), and the skin (by direct inoculation or by insect bite). In our view, infections occupationally acquired by meat handlers should be included in any consideration of meat-borne diseases, regardless of the route of conveyance, especially since in the majority of such instances the intestinal tract can serve, at least occasionally, as one of the portals of entry.

Pasteurelloses

Tularaemia is more likely to be contracted by a hunter as the result of a finger-prick or a tick-bite while skinning a rabbit or deer infected with *Pasteurella tularensis* than from eating the inadequately cooked flesh of such an animal. However, in Japan, an illness known as Ohara's disease or "yato-byo" (wild rabbit disease) has been recognized since 1837, when it was first described by a court physician as liable to follow the consumption of hare meat. About 30 years ago, this condition was shown to be serologically identical with tularaemia, and some 457 cases have been recognized

subsequently in Japan.[161] An abdominal or intestinal form of the disease, in which the route of infection is by mouth, is also recognized in the USSR. Further, the ability of sheep and cattle to act as reservoirs of *P. tularensis*, recently demonstrated in the USA, renders shepherds, cattlemen, and meat handlers liable to occupational infections therewith.

Certain other types of pasteurelloses may be more commonly transferred from animals to man than is at present realized, and a substantial proportion of these are apparently conveyed through the intestinal tract. For example, *P. pseudotuberculosis* is readily transmitted among various animal species, including rabbits, turkeys, goats, and swine, and has occasionally caused serious illness in persons having contact with such animals as cats and rabbits. In one recorded instance, garden soil polluted with cat faeces was the suspected source of a fatal human infection. In another instance, rabbit had been eaten before the onset of an acute abdominal illness, which was followed by evidence of generalized infection within a few days. The syndrome in man characteristically resembles severe typhoid fever. At autopsy, there are caseous necrotic foci in the liver, spleen, and mesenteric lymph-nodes, and intestinal ulcerations may be present.[55, 141]

P. multocida is a somewhat similar organism to the foregoing, and likewise primarily an animal pathogen. It seems liable to infect man typically through bites or scratches from cats, dogs, or rodents, kicks from a horse, and sundry skin lesions acquired in the course of handling animals. Other forms of intimate exposure to infected cattle and pigs, or to rabbit carcasses, including the consumption of rabbit meat, provide alternative portals of entry for this organism, which again causes a serious generalized infection in man.[141] Wild rats frequently harbour virulent strains of *P. multocida* in their throats,[187] and may serve as natural reservoirs from which human foodstuffs become contaminated with the infective agent.

Leptospirosis

In 1916, Inada and his colleagues[108] identified *Leptospira icterohaemorrhagiae* as the etiological agent of the human disease first described by Weil 30 years before. These Japanese workers stressed that the commonest vehicle of infection was water polluted with the excreta of rats carrying this spirochaete. The portal of entry could be either skin abrasions or the gastro-intestinal tract. The latter route has been regarded as uncommon because acid gastric juices soon destroy *Leptospira*; but undoubtedly some outbreaks of human leptospirosis have been due to drinking, or inadvertently swallowing, water contaminated by rats.[115, 206]

Moreover, experimental infection of animals by mouth has been demonstrated. Thus there is no theoretical reason why leptospirosis in man should not arise from ingestion of contaminated or infected meat. In fact, an

half of the sixteenth century, that rabies was conveyable to man by the bite of a dog; while Jenner, at the end of the eighteenth century, showed conclusively that cowpox could both infect and protect humans. Yet at the threshold of the twentieth century, Koch, the discoverer of the causal bacillus of human tuberculosis, denied the transmissibility of the bovine disease to man. Today we know that animals are subject to at least as many infections—viral, rickettsial, fungal, and helminthic—as man is heir to; and also, that in the many types and patterns of host-parasite relationships which have evolved over countless millenia, the hosts prove interchangeable surprisingly often. Moreover, in recent years, the problems involved in the epidemiology and control of these diseases have assumed previously unimagined complexities, since it is now clear that serious human infections can be acquired from animals which may be only mildly ill, or even apparently healthy.

Virchow applied the term "zoonoses" to primary infections of animals which are by any route conveyable to man. This section is concerned with those zoonoses, manifest or latent, which humans may acquire through the handling or ingestion of meat.

Zoonoses acquired Occasionally through the Intestinal Tract

Almost any zoonosis can be classified as potentially meat-borne, if the term "handling" be interpreted liberally enough. For in the course of capturing, slaughtering, skinning, dressing, or preparing animals for the table, many opportunities arise for infective agents to be transferred from them to man, through portals of entry other than the gastro-intestinal tract, such as the respiratory tract (by inhalation of droplets or dust), and the skin (by direct inoculation or by insect bite). In our view, infections occupationally acquired by meat handlers should be included in any consideration of meat-borne diseases, regardless of the route of conveyance, especially since in the majority of such instances the intestinal tract can serve, at least occasionally, as one of the portals of entry.

Pasteurelloses

Tularaemia is more likely to be contracted by a hunter as the result of a finger-prick or a tick-bite while skinning a rabbit or deer infected with *Pasteurella tularensis* than from eating the inadequately cooked flesh of such an animal. However, in Japan, an illness known as Ohara's disease or "yato-byo" (wild rabbit disease) has been recognized since 1837, when it was first described by a court physician as liable to follow the consumption of hare meat. About 30 years ago, this condition was shown to be serologically identical with tularaemia, and some 457 cases have been recognized

subsequently in Japan.[161] An abdominal or intestinal form of the disease, in which the route of infection is by mouth, is also recognized in the USSR. Further, the ability of sheep and cattle to act as reservoirs of *P. tularensis*, recently demonstrated in the USA, renders shepherds, cattlemen, and meat handlers liable to occupational infections therewith.

Certain other types of pasteurelloses may be more commonly transferred from animals to man than is at present realized, and a substantial proportion of these are apparently conveyed through the intestinal tract. For example, *P. pseudotuberculosis* is readily transmitted among various animal species, including rabbits, turkeys, goats, and swine, and has occasionally caused serious illness in persons having contact with such animals as cats and rabbits. In one recorded instance, garden soil polluted with cat faeces was the suspected source of a fatal human infection. In another instance, rabbit had been eaten before the onset of an acute abdominal illness, which was followed by evidence of generalized infection within a few days. The syndrome in man characteristically resembles severe typhoid fever. At autopsy, there are caseous necrotic foci in the liver, spleen, and mesenteric lymph-nodes, and intestinal ulcerations may be present.[55, 141]

P. multocida is a somewhat similar organism to the foregoing, and likewise primarily an animal pathogen. It seems liable to infect man typically through bites or scratches from cats, dogs, or rodents, kicks from a horse, and sundry skin lesions acquired in the course of handling animals. Other forms of intimate exposure to infected cattle and pigs, or to rabbit carcasses, including the consumption of rabbit meat, provide alternative portals of entry for this organism, which again causes a serious generalized infection in man.[141] Wild rats frequently harbour virulent strains of *P. multocida* in their throats,[187] and may serve as natural reservoirs from which human foodstuffs become contaminated with the infective agent.

Leptospirosis

In 1916, Inada and his colleagues[108] identified *Leptospira ictero-haemorrhagiae* as the etiological agent of the human disease first described by Weil 30 years before. These Japanese workers stressed that the commonest vehicle of infection was water polluted with the excreta of rats carrying this spirochaete. The portal of entry could be either skin abrasions or the gastro-intestinal tract. The latter route has been regarded as uncommon because acid gastric juices soon destroy *Leptospira*; but undoubtedly some outbreaks of human leptospirosis have been due to drinking, or inadvertently swallowing, water contaminated by rats.[115, 206]

Moreover, experimental infection of animals by mouth has been demonstrated. Thus there is no theoretical reason why leptospirosis in man should not arise from ingestion of contaminated or infected meat. In fact, an

instance is recorded of the disease developing in a man 8 days after consumption of ham kept in a cellar where it was gnawed by rats, and probably also polluted with their urine.[91]

Not only do *Leptospira* survive for weeks in stagnant water which is neutral or slightly alkaline, but some species actually grow on the skins of fish and in the adherent slime. Hence the proneness of fish handlers to acquire occupational leptospirosis.[4]

Meat handlers contract the disease rather less often, presumably because too few *Leptospira* survive on the polluted surface of infected meat. But *L. icterohaemorrhagiae* infections, which were probably caused by handling meat or offal contaminated by rats, have been identified in butchers. The fact that veterinarians and kennel-men are liable to become infected by handling dogs excreting *Leptospira*, particularly *L. canicola*, in their urine, suggests that canine pollution of meat could also result in human leptospirosis.[145]

In recent years, reports have come from several continents of *L. pomona* infections in swine-herds and cattle-men, stockyard and slaughterhouse workers, especially in areas with heavy rainfall.[27, 120, 206] Leptospira excreted by infected stock, and surviving in mud and water around a farm, can penetrate the human skin through minor lesions and mucous membranes rather than through the digestive tract. However, the proven occurrence of these infections in livestock used for human food points to additional, though admittedly remote, possibilities of leptospirosis being acquired by man through ingestion of improperly cooked meat.

Erysipelothrix

Erysipelothrix rhusiopathiae is the causative organism of swine erysipelas, which has been a serious veterinary problem in Europe for over a century, and has assumed severe epizootic proportions in recent years in North America and elsewhere. This organism is apparently responsible also for polyarthritis in sheep, and is pathogenic for many other mammals, large and small, domestic and wild. Turkeys, ducks, and fowl are prone to a septicaemic form of infection, while *E. rhusiopathiae*, or closely related species, may be present in freshwater fish and in the slimy coating on salt-water fish and marine mammals.[222] Various human syndromes due to *Erysipelothrix* infections are recognized.[58] Most of these infections are occupationally acquired and usually take the form of a cutaneous erysipeloid condition, which may be either mild and localized or severe and widespread ; a fatal septicaemic form also occurs—for example, a butcher who lacerated his thumb on a meat bone developed cellulitis locally, followed by evidence of a generalized infection, with irregular fever, purpuric rash, and blood

cultures positive for *E. rhusiopathiae*. The patient died of subacute bacterial endocarditis six months after the injury.[121]

Among animals, according to some authorities,[222] *Erysipelothrix* infections are mainly excreta-borne. Since the organisms are present in the tissues of severely infected swine or poultry, it is surprising that there are so very few authenticated instances of human infections acquired by the digestive tract. The best-known example was reported from France about 20 years ago.[64] A man felt malaise a few hours after a meal of salt pork. Generalized pruritis soon developed, with an erysipeloid eruption localized to the ears and cheeks. Over the following weeks, evidence of generalized infection appeared, including profound anaemia, with blood cultures yielding an organism resembling *E. rhusiopathiae*. A slow recovery was complicated by nephritis, and the patient died about two months after the onset of illness.

Human susceptibility to this infection by the intestinal route is presumably of a low order. Otherwise, outbreaks could be anticipated as a result of consuming swine or turkeys slaughtered to eradicate infection in herds or flocks. Nevertheless, the sale of infected carcasses should not be permitted; for *Erysipelothrix* organisms seem sufficiently durable to survive imperfect or uneven cooking procedures, and have been shown to retain their virulence for 10 weeks in pork exposed to commercial methods of salting or pickling, and for over 3 months in well-smoked hams.[64]

Incidentally, North Sea and Atlantic fishermen, Greenland sealers,[181] and Antarctic whalers [101] are occupationally liable to intractable cellulitis of traumatized fingers and hands, although catching apparently normal fish and marine mammals. These infections are regarded by some authorities as also caused by *Erysipelothrix* organisms, while others consider kindred species of the genus *Corynebacterium* to be responsible.

Listerellosis

In 1926, Murray and co-workers [155] identified a previously undescribed bacillus as the causal agent of an infectious disease in rabbits, characterized by a large mononuclear leucocytosis. This organism, which they named *Bacterium monocytogenes*, is now known to be widely dispersed throughout the animal kingdom and in every continent. It has been isolated already from natural disease in at least 18 species of wild or domestic mammals and birds, including cattle, sheep, goats, swine, chickens, rabbits, and smaller rodents such as gerbils, lemmings, and rats.[117, 154] A peculiarity of *Listeria monocytogenes* infections is the variability of syndromes provoked in different animal species. Man is occasionally involved, new-born

infants being especially susceptible to generalized and usually fatal infection with *Listeria* apparently derived from the vagina of their mothers.

Little is known about the natural habitat of these organisms, or about the modes of transmission of the disease, whether between individual animals of different species, between animals of the same species (as, for example, in epizootics affecting lemmings), or between animals and man. No examples are known of person-to-person conveyance, except for the mother-to-infant transfer cited above; and from presumptive evidence, and by analogy, it may be inferred that animals probably serve as reservoirs of *Listeria* infection for man. As baby rabbits and white mice have been infected experimentally by the oral route, the gastro-intestinal tract cannot be excluded as a possible portal of entry in either animal or human listerellosis. Moreover, since the infection may arise in persons with no history of occupational or fortuitous contact with animals, inadequately cooked meat must be reckoned as one of the potential sources of this mysterious disease in man.

Miscellaneous infections

Although there is little point in delving into very rare contingencies, it seems well to recollect that the epidemiology of what is, perhaps, the commonest of all zoonoses—brucellosis—was elucidated only quite recently. In the fairly near future, some of the rarer zoonoses, such as have just been considered, may loom larger as veterinary and public health problems, while certain agents at present regarded as exclusively animal pathogens may some day be proved to be occasionally dangerous to man.

For instance, *Vibrio foetus* was formerly known only as an unusual cause of abortion in cows and ewes in parts of Europe and North America. In 1950, a report appeared from France of 3 cases of febrile illness, affecting women in the last trimester of pregnancy, terminating in abortion.[214] Blood cultures were positive for *V. foetus*. As in the animal disease, the placenta showed severe pathological changes, and recovery was uneventful after its expulsion. A recent report [217] of the isolation of *V. foetus* from the blood-stream of a 31-year-old man with a febrile illness, preceded by an unexplained paralysis of one leg, raises possibilities of latency of infection, and also of the digestive tract's serving as portal of entry, despite negative transmission experiments in animals. This patient had had no occupational contact with cattle or sheep since boyhood, when he had looked after cows and had later been apprenticed to a harness-maker. Within the two years preceding onset of his illness, however, he had first followed a stringent milk diet on account of gastric ulcer, then undergone gastrectomy, and finally, during convalescence, had sought to restore his strength by drinking 1 litre of raw beef serum brought to him daily from

the abattoir by a friend. Since *V. foetus* has been isolated from the blood-stream and liver of infected animals, it would seem that meat handlers are exposed to some degree of risk.

A brief reference is relevant to viral and rickettsial pathogens which may be occasionally meat-borne. The adaptability of the ornithosis or psittacosis group of viruses to numerous mammalian and avian hosts, including chickens, ducks, and turkeys, places them in the category of infective agents which can be acquired by handlers of poultry and perhaps other kinds of meat. However, there is no evidence to date that infective doses of these viruses can be absorbed through the digestive tract. The transmission of psittacosis virus from wild birds to Australian aborigines, with consequent development of circulating antibodies, is more probably due to inhalation of infective particles from plucked feathers than to ingestion of the flesh, even though it may have been consumed raw.[13]

Foot and mouth disease virus is of low infectivity for man, judging by the fact that human cases are seldom noted among persons intimately exposed to it, as when slaughtering condemned herds. When infection does occur, the mode is generally through contamination of skin abrasions with animal saliva; but the intestinal mucosa may also prove permeable to virus conveyed by milk and dairy products, or possibly by meat products. The presence of the virus has been demonstrated in the faeces of a person living in an infected area.[122]

Insect bites are an important means by which persons handling livestock, or concerned with wild life in any capacity, may acquire bacterial, rickettsial, or viral infections in areas where animals are liable to act as reservoirs for these pathogens. Thus, in many instances of human tularaemia acquired from hares, as reported from Japan, France, and the USSR, certain species of ticks have undoubtedly served as vectors of *P. tularensis*. Similarly, in various western regions of the USA and Canada, the mosquito *Culex tarsalis* has frequently conveyed the virus of western equine encephalomyelitis to man from horses, pigs, chickens, and various other mammalian and avian hosts. In the transmission of rickettsial infections from animal reservoirs to man the intermediacy of biting arthropods is generally essential, the most notable exception being Q fever.

Although *Rickettsia burnetii* probably subsists in nature through a primary cycle involving small vertebrates and their tick ectoparasites, human infection is seldom traced to this cycle. While hiatuses remain in our knowledge of the epidemiology of Q fever, there is general agreement that infected cattle, sheep, or goats are the probable source of this still rather novel but certainly widespread disease. Since 1937, when it was first recognized as a new entity in Queensland,[44] outbreaks of Q fever have been reported from several European countries, the British Isles,

many parts of Africa, and very recently the USSR ; and in all these areas, slaughterhouse workers have shown an outstanding predisposition to this infection. Dairy employees and persons handling animal hides, wool and hair are also apt to contract Q fever, while outbreaks apparently due to consumption of milk or milk products have been reported.

The explanation for these facts appears to lie in the laboratory findings that *R. burnetii* is excreted in the milk, and harboured in the placenta, of infected cattle and goats ; that very large numbers of rickettsiae are excreted by infected ticks in their faeces ; and that these rickettsiae are unusually resistant to desiccation and perhaps to pasteurization temperatures. From such data it is not difficult to visualize that in addition to the milk, the hides, feed, straw, bedding, and atmospheric dust of an abattoir or dairy barn can become heavily polluted with rickettsiae, and serve as a source of infection to man by inhalation or ingestion. A more directly meat-borne etiology for Q fever is conceivable, but no instance of this appears to have been recorded.

Control measures

The foregoing examples of the less familiar kinds of infection conveyable to man through the occupational handling of meat, or more rarely through its consumption, illustrate the still unfolding complexity of zoonotic epidemiology. Although their control has grown so unexpectedly intricate since Virchow's time, it fundamentally involves tracing and interrupting the routes and modes of spread of the causal agents among the animals themselves, and also from animal to man. The extent to which control is feasible, and the appropriate manner of going about it, has been made as far as possible self-evident for each disease coming under review. Further details cannot be given here, but a few general observations seem indicated. In some of the instances cited, even though the transmission mechanisms have been elucidated, insuperable obstacles may be encountered in eliminating the primary reservoirs of infection, because these are often wild animals, and therefore—whether rare or prolific—more or less elusive. Again, if the secondary hosts be farm animals, to diminish contacts between members of a herd seems about as difficult as to prevent access of rodents and insects to barn or pasture. By contrast, some of the measures necessary for preventing animal-to-man conveyance may be relatively simple and practicable ; for example, protection of animals or man by specific vaccination wherever economically and immunologically feasible ; better drainage and improved excreta-disposal arrangements in and around dairy barns and piggeries ; safeguarding of the hands and feet from traumatic inoculation of pathogens by wearing gloves and boots during occupational exposure ; careful washing of hands after contact with animals ; and

thorough cooking of all meat. Faithful application of such measures, however, is often difficult to secure, for the community customs of generations, and the life-long habits of individuals, may first have to be overcome by patient instruction.

Commoner Zoonoses acquired Occupationally by Meat Handlers

Certain better known zoonoses, such as anthrax, bovine tuberculosis, and brucellosis, are also liable to be acquired occupationally by meat handlers. These will be considered in somewhat more detail.

Anthrax

The microbial cause of anthrax, *Bacillus anthracis*, was probably the first disease-producing bacterium to be seen. Almost exactly a century ago, Pollender reported from Westphalia that in 1849 he had noted the presence of rod-like bodies in the blood and spleen of cows which had died from anthrax.[172] Thirty years after that observation, Pasteur began his classic work on this disease, which culminated in the dramatically successful field trial at Pouilly-le-Fort, in 1881, demonstrating that cows and sheep could be actively immunized by means of attenuated vaccine.[168]

Countries maintaining efficient veterinary services face little danger of anthrax again becoming rampant; but it remains very widespread, and in parts of Africa, India, and China still takes a heavy toll. In Iran, in 1947, one million farm animals died from the disease.[221] In Europe, until a few decades ago, certain countries also suffered heavy losses from it. For example, in the Novgorod district of Russia, during the period 1867 to 1870, anthrax was the recorded cause of death of 56 000 horses, cattle, and sheep, and of 525 men. Nowadays, the animal disease is uncommon except in Italy, Portugal, Spain, Turkey, and Yugoslavia.[60] In Canada, anthrax is very rare, but in the USA, although the incidence of both animal and human forms is declining, some enzootic areas persist. Over the five-year period 1939-43 there were 408 reported cases of human anthrax, the sources of infection being wool or hair in 60%, hides and skins (mostly imported from the Far East) in 20%, and infected animals or soil in 16%.[192] In the United Kingdom, the incidence of human anthrax has been markedly reduced since full effect was given to the Anthrax Prevention Act of 1919, which required disinfection of imported wool and hair. Sporadic cases still occur, however, with occasional outbreaks among persons handling less familiar industrial products of animal origin, such as crushed dried bones imported in sacks from India and Pakistan.[41]

The persistence of this zoonosis through the centuries seems mainly due to the remarkable viability of anthrax spores, which Pasteur and his associates showed might survive in soil for 12 or more years,[167] and which have been isolated from a pond in a pasture where the disease had occurred 18½ years before.[95] In the laboratory, spores have been kept viable for 60 years.[211]

Stringent precautions against the importation of infected animals and their products greatly lessen the risk of introducing anthrax into virgin territory. In endemic or epidemic areas, the numbers of spores in the soil are apparently reduced by a combination of measures, such as notification of the disease, isolation and ruthless destruction of sick animals or carcasses, followed by deep burial and disinfection of surroundings, and vaccination of susceptible livestock. Earthworms, however, are no less assiduous in turning up castings than they were in Pasteur's day, and spores are always liable to be carried far afield by carrion birds on their feet and beaks, and by dogs through their faeces.

Until anthrax is eradicated in domestic animals, it will inevitably be a potential hazard to persons occupationally exposed to such animals or their products. This hazard is best diminished by carefully teaching the precautions which industrial hygienists regard as desirable for preventing access of infection through the skin (malignant pustule), or the lungs (wool-sorters' or rag-sorters' disease), to persons employed as veterinarians, meat inspectors, farmers, cattle-men, butchers, tanners, and in other industries concerned with hides, hair, wool, or bristles. Occasionally, raw meat may convey fulminating anthrax to a casual handler, as in a briefly reported instance of a Slovak peasant, who cut his finger while handling meat and died within 4 days of septicaemia and haemorrhagic leptomeningitis due to *B. anthracis*.[69] The rapidly fatal intestinal form, acquired by ingestion of infected meat, is fortunately very rare, owing to the prohibition in most countries of the sale of carcasses suspected of infection with *B. anthracis*. It is relevant, however, to recollect here that the communicability of anthrax was first established by Eilert in 1836 by either feeding or inoculating healthy animals with infected blood. As some spores are able to survive ordinary cooking or even canning procedures, it is not surprising that intestinal anthrax is reported to have occurred among gipsies and South African natives, who are often careless about both the source of meat and its cooking temperature.

Bovine tuberculosis

In North America, bovine tuberculosis has greatly diminished in recent years, mainly owing to nation-wide programmes for detecting and

eliminating tuberculin reactors among cattle. In the USA, during 1949, only about 0.1% of cattle and 0.02% of swine slaughtered and federally inspected were condemned because of tuberculosis. Twenty-five years before, the corresponding percentages were roughly tenfold greater. In Canada, in 1953-54, of a total cattle population estimated at eight and a half million, 84.4% had been tuberculin tested. Nearly five million head of cattle were distributed in 355 "accredited areas" having reactor percentages not exceeding 0.5%.[21]

In many other parts of the world, where for various reasons such programmes have been carried out less vigorously, tuberculosis of bovine origin still causes fatalities and much disability, especially among children. Raw milk and milk products are certainly the main vehicles for this infection, and efficient pasteurization is by far the best means of prevention. Tuberculous carcasses, however, also present certain hazards. Obviously, the meat inspector, abattoir worker, or butcher who merely removes the affected lymph-nodes from animals in otherwise good condition, can contract tuberculosis percutaneously, and possibly by other routes. Less well recognized are the opportunities for transfer of infection, through faulty slaughterhouse practices, from diseased to healthy carcasses. Current meat-inspection procedures for tuberculosis are mainly designed to differentiate between carcasses showing only local manifestations, which are usually released for human consumption, and those displaying evidence of generalized disease, which are condemned in most countries because tubercle bacilli presumably have invaded the blood-stream and been disseminated into the muscles and viscera. More attention should be paid to hygienic precautions designed to minimize the risk of pollution conveyed to healthy carcasses within the abattoir itself.

Finally, in those countries where selected portions of quite severely infected carcasses may be passed for human consumption, provided such meat be designated as of inferior quality, it should be noted that bovine tubercle bacilli may be demonstrably present in the meat of animals showing only minor lesions.[146] By guinea-pig inoculation and by culture, *Mycobacterium tuberculosis* was isolated from the muscles of 62.8% of animals showing acute generalized tuberculosis at autopsy, and also from 10.8% of meat samples from animals with only small isolated lesions in one or more organs. In the latter group, a direct relation was apparent between the degree and kind of lesion, particularly when in the lungs, and the incidence and numbers of tubercle bacilli isolated from the musculature. Such findings suggest that in some parts of the world, meat-inspection regulations and procedures respecting tuberculous cattle are probably too lenient.

Brucellosis

This disease has had a very different history from anthrax and bovine tuberculosis, which were known as specific diseases of animals long before human susceptibility to them became recognized. After Bruce's report [17] in 1887 on the isolation of a micro-organism from the spleen of several cases of Malta fever, 20 years elapsed before the Mediterranean Fever Commission published its conclusions that the usual mode of infection was through ingestion of raw milk from apparently healthy goats.[183] This infective agent, mistakenly called by Bruce a " micrococcus ", is now generally known as *Brucella melitensis.* Two closely related species, *Br. abortus* and *Br. suis*, were isolated by Bang in Denmark, in 1897,[8] and by Traum in the USA, in 1914,[208] from the aborted foetuses of cows and sows, respectively. Sporadic cases of obscure human illness caused by these organisms were first identified about 30 years ago. Gradually, it became evident that in areas where either manifest or inapparent *Brucella* infections were harboured by goats, cows, and swine, or less commonly by sheep, horses, and dogs, a wide variety of human illnesses might be traced to these domestic animal sources. Nicolle's forecast of half a century ago, that " Mediterranean fever is a disease of the future ", began to seem quite prophetic. Indeed, brucellosis—to use the term now generally preferred to the countless other names given to this disease, before and since Bruce's discovery—is probably the commonest of all the zoonoses.

The baffling havoc wrought, and the elusive syndromes provoked, by these pathogenically versatile but biochemically unassuming micro-organisms, have been thoroughly reviewed elsewhere, in book form.[1, 106] Also, the salient features of the complex problems of brucellosis control have been outlined in an authoritative pamphlet, from the standpoints of both public health and of the economic losses suffered by animal husbandry and industry.[223] The task of considering the epidemiology of meat-borne brucellosis is more restricted and comparatively simple. For although this disease may be contracted through consumption of raw milk or milk products from *Brucella*-infected cows or goats, it is very seldom acquired through the ingestion of meat or meat products from infected cattle, hogs, or sheep. Presumably, the relatively few organisms which may be present initially in the muscles and viscera of such livestock are reduced to negligible numbers by even imperfect cooking procedures. Besides, the gastric juices apparently exert some bactericidal effect upon *Brucella* organisms, as judged by the apparent failure of some persons to become infected despite repeated ingestion of considerable numbers of these organisms in uncooked dairy products. By contrast, the notorious proneness to infection of laboratory workers handling *Brucella* cultures indicates that minor and sometimes imperceptible lesions of the skin and

mucous membranes may serve readily as portals of entry—hence the marked predisposition to brucellosis shown by occupational handlers of animals in areas where the disease is enzootic.

Jordan [1] determined the specific morbidity-rates for brucellosis per 100 000 persons exposed occupationally to varying degrees of contact with farm animals. In Iowa, over the period 1940-47, some three-quarters of roughly 2600 persons with brucellosis gave a history of such contact. In this group, veterinarians, packing-house employees, and male farm workers, showed outstandingly high morbidity-rates of 562, 276, and 59, respectively; while the rate for a "no-contact" group of some 600 cases was only 2.

"Contact" or occupational modes of acquiring brucellosis are paramount in hog-breeding areas, where the organism generally responsible is *Br. suis*. In cattle-raising and dairy-farming areas, *Br. abortus* infections are more likely to predominate, and the human disease may be either milk-borne or occupationally acquired. When goats serve as reservoirs of *Br. melitensis* infection, their milk is the customary vehicle, but each *Brucella* species can adapt itself to several alternative animal hosts, as well as to man. Thus, the epidemiological patterns fluctuate from area to area, according to the extent and nature of the local livestock industry, the average incidence of infection in the herds, and kindred circumstances; even in a given region the pattern may change. Before any programme for the control of brucellosis is devised, a preliminary study of locally prevailing circumstances is therefore essential. In fact, in many parts of the world, as Dalrymple-Champneys stressed in England,[40] the extent of the brucellosis problem will probably be under-estimated, and will certainly not be clearly visualized, until a careful search is launched.

Despite variations in detail, control programmes must follow certain basic principles. Since human brucellosis is a self-limiting disease, that is, it is not as a rule communicable from man to man, preventive measures should be directed against enzootic-promoting factors and routes of infection-transmission from animal to man. First, infected animals should be identified by sero-agglutination tests, and then eliminated, preferably by slaughter, with government compensation. As a corollary, it follows that importation of fresh reactors into the area should be prohibited. Further, since cows can become infected with *Br. melitensis* or *Br. suis*, dairy herds should be segregated from untested goats or pigs; and likewise, *mutatis mutandis*, for the latter animals. Moreover, when drastic measures are necessary, as at times in swine brucellosis, it is futile to dispose of the whole herd for slaughter unless all equipment and pens be then thoroughly cleaned and disinfected, and pastures drained and ploughed. Application of the foregoing principles has shown promising results in the USA, Canada, and the Scandinavian countries. Secondly, attempts can be made to protect

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mucous membranes may serve readily as portals of entry—hence the marked predisposition to brucellosis shown by occupational handlers of animals in areas where the disease is enzootic.

Jordan [1] determined the specific morbidity-rates for brucellosis per 100 000 persons exposed occupationally to varying degrees of contact with farm animals. In Iowa, over the period 1940-47, some three-quarters of roughly 2600 persons with brucellosis gave a history of such contact. In this group, veterinarians, packing-house employees, and male farm workers, showed outstandingly high morbidity-rates of 562, 276, and 59, respectively; while the rate for a "no-contact" group of some 600 cases was only 2.

"Contact" or occupational modes of acquiring brucellosis are paramount in hog-breeding areas, where the organism generally responsible is *Br. suis*. In cattle-raising and dairy-farming areas, *Br. abortus* infections are more likely to predominate, and the human disease may be either milk-borne or occupationally acquired. When goats serve as reservoirs of *Br. melitensis* infection, their milk is the customary vehicle, but each *Brucella* species can adapt itself to several alternative animal hosts, as well as to man. Thus, the epidemiological patterns fluctuate from area to area, according to the extent and nature of the local livestock industry, the average incidence of infection in the herds, and kindred circumstances; even in a given region the pattern may change. Before any programme for the control of brucellosis is devised, a preliminary study of locally prevailing circumstances is therefore essential. In fact, in many parts of the world, as Dalrymple-Champneys stressed in England,[40] the extent of the brucellosis problem will probably be under-estimated, and will certainly not be clearly visualized, until a careful search is launched.

Despite variations in detail, control programmes must follow certain basic principles. Since human brucellosis is a self-limiting disease, that is, it is not as a rule communicable from man to man, preventive measures should be directed against enzootic-promoting factors and routes of infection-transmission from animal to man. First, infected animals should be identified by sero-agglutination tests, and then eliminated, preferably by slaughter, with government compensation. As a corollary, it follows that importation of fresh reactors into the area should be prohibited. Further, since cows can become infected with *Br. melitensis* or *Br. suis*, dairy herds should be segregated from untested goats or pigs; and likewise, *mutatis mutandis*, for the latter animals. Moreover, when drastic measures are necessary, as at times in swine brucellosis, it is futile to dispose of the whole herd for slaughter unless all equipment and pens be then thoroughly cleaned and disinfected, and pastures drained and ploughed. Application of the foregoing principles has shown promising results in the USA, Canada, and the Scandinavian countries. Secondly, attempts can be made to protect

healthy animals by active immunization. Considerable success has been achieved in some countries, for example, Great Britain and New Zealand,[40] and on a smaller scale in Canada, [21] by calf-hood vaccination with the attenuated *Brucella abortus* strain 19 vaccine. Unfortunately, efforts to protect swine, goats, and sheep by similar means have been so far disappointing.

Interruption or severance of the route by which *Brucella* organisms are transmitted from animals to man is a simple problem when milk is the main vehicle; for proper pasteurization of milk and milk products effectively abolishes this source of brucellosis, regardless of the *Brucella* species and host animals involved. However, no such straightforward measure is available for preventing occupational brucellosis; for here, by definition, the handling of animals, living or dead, is unavoidable. Some lessening of risks might be accomplished by educating those in hazardous occupations as to the nature of the dangers they face. Stress should be laid upon the desirability of protecting their skin and mucous membranes from intimate, frequent, and extensive contact with animal tissues and discharges. It seems unlikely, however, that farm workers would take to wearing gloves before attempting to handle struggling animals, when veterinarians often fail to protect their hands and arms from infected uterine discharges in manually removing a cow's afterbirth. Nor could it be expected of retail butchers that they would willingly hamper their fingers with gloves, when workers in large meat-packing plants can hardly avoid wallowing in the blood, tissues, and excrement of hundreds or thousands of animals daily. In such conditions, *Brucella* organisms are liable to be scattered on the floors and walls of the establishment, and even to be air-borne. There is little chance of eliminating brucellosis among meat handlers by the educational approach until slaughterhouse methods undergo radical changes. Further progress may be sought more hopefully through investigations of new immunization techniques, and through more widespread and rigorous adoption of blood-testing and reactor-eliminating campaigns.

Zoonoses acquired Chiefly through the Intestinal Tract

Various species of animals are liable to excrete bacterial and helminthic pathogens, which are capable of surviving and even proliferating in the human gastro-intestinal tract. The chief reservoirs of such organisms are animal intestines, and a high proportion of zoonoses in this category are therefore excreta-borne, either by pollution of handlers' fingers, or through contamination of foodstuffs with the faeces of livestock, rodents, and even household pets. In certain circumstances, these enteric pathogens

migrate from their customary habitat by traversing the intestinal mucosa, and invading the blood-stream of the host animal, so that its tissues become potentially infective for handlers and consumers. Hence this section will consider the routes and mechanisms by which harmful organisms are apt to pass from the intestines of animals more or less directly into the human digestive tract, with meat as the medium of conveyance.

Salmonelloses

Mode of infection. In 1885, Salmon & Smith isolated from swine with hog cholera a motile bacillus which they called *Bacillus suipestifer*,[186] and which later became known as *Salmonella choleraesuis*. Eventually this organism was shown to play only a secondary role in the porcine disease; but it remains important, both as an occasional cause of dangerous, typhoid-like infections in man, and as the officially recognized prototype for the *Salmonella* genus.

Nearly 400 distinct serotypes have now been differentiated in this genus, by analysis of their flagellar and somatic agglutinogenic structure according to the Kauffmann-White schema. Some of these types are primarily animal pathogens, while one or two, such as *S. typhi*, are generally considered exclusively pathogenic for man. However, the great majority of salmonellae so far identified appear able to infect, or to be carried by, an astonishing range of alternative hosts—reptiles, birds, and mammals, including man.

The most direct route by which salmonellosis can be conveyed from animals to man is through consumption of inadequately cooked meat, such as beef, pork, or turkey, from cows, pigs, or poultry with generalized infection at the time of slaughter. Among several classic examples of such occurrences, the following seem particularly relevant. In 1888, a sick cow was emergency-slaughtered, and its carcass salvaged and sold, at Frankenhausen, Germany. All 58 consumers of the meat fell ill with acute enteritis. One person, who had eaten about 1½ lb. (700 g), died in 36 hours. From the meat, and from the victim at autopsy, Gärtner isolated an organism which he called *Bacillus enteritidis*.[74] About 10 years later, De Nobele[42] described another organism, which he isolated from patients with enteritis, and from meat suspected as the vehicle, at Aertrycke in Belgium. The incriminated bacillus for many years bore the name of this village, but is now known as *Salmonella typhimurium*, and is generally considered the most prevalent cause of meat-borne salmonellosis in man. This is no doubt due largely to its very wide distribution throughout the animal kingdom, including Gila monsters and garter snakes as well as cows and chickens, and ranging from turkey to turtle, from mouse to moose. Indeed, *S. typhimurium* especially displays the capacity to pass from animal to

man and back again by devious routes, epitomized in a facetious quatrain which appeared anonymously in *The Lancet* a few years ago :

"An infection in beavers was transmitted to retrievers,
And carelessly contracted by a vet,
While the organism injected in a toad in Timbuktu,
Was recovered from a tadpole in Tibet."

Although the three organisms, *S. typhimurium*, *S. choleraesuis*, and *S. enteritidis* fall into different serological groupings (B, C, and D respectively) within the Kauffmann-White schema, they all show a propensity for invading the tissues of livestock and poultry, thereby jeopardizing the human consumer. *S. typhimurium* is the worst offender, not infrequently causing septicaemia in calves, cows, lambs, and turkeys, while *S. choleraesuis* mainly confines itself to pigs. These, moreover, are by no means the only species or serotypes liable to be involved in this form of meat-borne salmonellosis. *S. newport*, *S. oranienburg*, *S. dublin*, *S. bovis morbificans*, and many other types, have been implicated in various parts of the world.

The mortality-rate among animals with these generalized infections is usually high, and their carcasses are apt to show easily discernible abnormalities, such as emaciation and discoloration, haemorrhagic or purulent lymph-nodes, and other pathological foci or exudates. A scrupulous inspector will rigidly ban all obviously unhealthy meat from human consumption; but the carcasses of such livestock, including aborted or sickly calves (" slink " or " bob " veal), sometimes find their way surreptitiously to illicit markets, with disastrous results. For instance, in Italy, in 1938, some 30 persons developed acute enteritis, and 2 died, as a result of eating sausages prepared from secretly slaughtered swine infected with *S. choleraesuis*.[77] Again, 50 years after *S. typhimurium* was first incriminated in meat-borne infection, it caused an epidemic in a German hospital, affecting over 150 inmates. The source was sausage meat, derived from four cows emergency-slaughtered one week previously.[171]

Latent infection also causes trouble, in that animals surviving an epizootic, or slaughtered at its onset, can pass scrutiny and be openly marketed, although their flesh, viscera, and intestinal contents may be infective. To illustrate the fact that meat products can appear sound and yet be deadly, Van Ermengem has related an incident occurring in 1896 in Moorseele, Belgium.[212] A meat inspector who had approved a carcass volunteered to test his conviction that the meat was safe by eating some sausage made from it. In six days he died of salmonellosis. Education of the farmer and the general public as to the potential dangers will greatly assist the public health and veterinary authorities in controlling the sale of meat from animals known to have been ailing or associated with infected herds or flocks.

Unfortunately, neither the farmer, the inspector, nor the general public can identify the " healthy carrier " status in cow or pig, chicken or turkey. There is abundant laboratory evidence from many countries that salmonellae are carried in the intestines, and sporadically in the tissues, of substantial percentages of apparently healthy livestock destined for human consumption, as well as of rodents (rats and mice), and of household pets (dogs and cats), which intermingle with these farm animals and with their future consumers. It is impossible to review here the extensive literature reporting such surveys, but an attempt will be made to summarize the data in general terms, bearing in mind that surveys conducted more than 10 years or so ago are of doubtful validity owing to the great improvements effected since then in selective bacteriological media.

Although every country apparently suffers from salmonellosis among its animal and human populations, there are marked regional differences of incidence and type distribution. For example, Japan differs in these respects from Venezuela, and Australia from Scandinavia. Moreover, Florida's pattern does not conform to that of the USA as a whole ;[57, 70] and the salmonellae in British Columbia seem generally more varied and exotic than those encountered so far in other parts of Canada. These differences doubtless stem partly from climatic and ecologic factors beyond human control, and partly from migrations of people and fluctuations of fauna which are more pronounced in some areas than others.

In any given region, the spectrum of enzootic and endemic *Salmonella* types tends to shift and broaden. Such changes, when noted a few years ago in the British Isles and Germany, were ascribed to the importation of dried egg powder from North America, and of meats from foreign countries, respectively. Another sort of explanation seems more applicable to the situation in a rather sparsely settled area such as British Columbia, where before 1945 the only salmonellae isolated from human faeces had been *S. typhi*, *S. typhimurium*, *S. paratyphi* B. and *S. newport*. By 1955, using essentially the same laboratory procedures, the number of serotypes identified in the Province had risen to 42. During the intervening decade, this region experienced a rapid increase in population, with an especially heavy influx of migrants and transients, which could account both for the expanding variety of *Salmonella* types and for the man-to-man conveyance of most of the reported salmonelloses. However, a possible link with animal reservoirs is suggested by the fact that either before or since the isolation of some of the rarer serotypes from humans in British Columbia, these were identified in animals in the neighbouring Province of Alberta, which happens to have maintained a special interest in veterinary surveys of this kind.

In some communities, a fairly close parallelism has been demonstrated between the serotypes isolated from human cases of salmonellosis, and

those predominating in local animals. Several surveys in the USA, notably one conducted in Illinois about 5 years ago, have shown a type distribution in man similar to that prevailing in local poultry—except for the special liability of the latter to *S. pullorum* infection.[62] In Florida, the *Salmonella* types found in dogs [72] and swine [73] have been strikingly similar to those encountered in man.[70] Again, in the United Kingdom, dogs, cats, and pigeons,[36] as well as horses, pigs, turkeys, geese, ducks, and chickens,[191] have carried *Salmonella* types commonly involved in human infections; while in Japan, types from human sources corresponded frequently with those isolated from dogs, cattle, swine, rats, and poultry.[185, 202]

Such parallelisms, based on bacteriological examinations of animal and human faeces, can be traced a stage further to the flora of meat products in samples taken from abattoirs, wholesale meat markets, and butchers' shops. In the USA, a survey of retail meat products collected in or near Lexington, Kentucky, in 1943, showed 13 out of 250 samples, or 5.2%, to be positive for *Salmonella* types potentially pathogenic for man, their probable source being the animals from which the meat came.[26] Pork liver showed the highest incidence (6 positive among 30 samples, or 20%) and beef the lowest incidence (1 positive among 40 samples, or 2.5%). A more extensive sampling of foods purchased on the open market in Illinois in 1950, revealed salmonellae in only 0.2% of 512 beef specimens, but in 17.6% of 102 specimens of hamburger hash. Similar organisms were isolated from 10.8% of 748 uninspected poultry carcasses, and from 26.8% of 101 uninspected pork samples. The incidence was considerably lower in federally-inspected meat, being only 0.9% in 327 birds, and 14.3% in 573 samples of pork. These salmonellae (again originating apparently in the animals themselves) were of serotypes commonly involved in human infections.[62] An even more recent survey in Florida [71] showed salmonellae to be present in 23% of 217 samples of fresh pork sausage, and in 12.5% of 127 samples of smoked pork sausage.

These percentages are disconcertingly high for a country whose large packing-plants display many awesomely efficient features; and they are the more surprising because the incidence of human salmonellosis is generally reckoned to be lower in the USA than in many European countries. Yet some of these countries can point to a relatively sparse distribution of salmonellae in meat. For example, in several public health laboratories in England over the period 1950-53, samples from freshly slaughtered carcasses of cattle and pigs were cultured for salmonellae. In the cattle survey, *S. dublin* was isolated from 13.6% of 206 liver samples, whereas from 904 faeces, *S. dublin* and *S. typhimurium* were each isolated three times—a carrier rate of only 0.7%. (For some reason, *S. dublin* has been more often involved in milk-borne than in meat-borne outbreaks.) No salmonellae were isolated from the liver and spleen of 494 calves. The

findings in pigs stand in even greater contrast to the USA figures. *S. dublin* was isolated in one northern laboratory from 6 out of 452 samples of bile, but no salmonellae were detected by the other participants in a survey of some 3000 samples of bile, liver, spleen, and faeces ; while 1555 peritoneal swabs and mesenteric glands yielded only 4 strains—that is, an incidence of 0.25%.[176]

In Italy, about 8 years ago, no salmonellae were detected in 55 samples of recently manufactured sausages from the Siena retail market ; while only 3 out of 45 links (6.7%), manufactured over a month before, yielded *S. choleraesuis*.[10] Again, in Spain, a recent bacteriological survey of mesenteric lymph-nodes from healthy pigs slaughtered for human consumption showed the presence of well-known types of salmonellae in 15 out of 200 carcasses, or 7.5%.[174] In Egypt, where human liability to food-borne infection is notorious, no salmonellae were isolated from pooled samples of liver, spleen, mesenteric glands, and muscles of sheep, cattle, camels, and pigs, slaughtered in 1950 at the Cairo abattoir.[59]

Such discrepancies cannot be satisfactorily explained merely by postulating an especially large percentage of failures to diagnose and report human salmonellosis in the USA ; nor by suggesting that countries vary greatly in the efficiency of their bacteriological techniques for isolating enteric pathogens, since these are now fairly standardized. A more plausible hypothesis is that the high percentages of *Salmonella*-infected meat products in some parts of the USA are largely due to a combination of ante-mortem transfer of infection among animals on their way to slaughter, and of post-mortem faecal pollution of their carcasses in the abattoir. Admittedly, the marketing, transport, and slaughtering processes of the modern meat industry may carry animals to their doom much faster than they went two or three centuries ago, when cattle slowly trekked in droves by strait and road from the Isle of Anglesey to the London markets ; [53] but the jostling, overcrowding, fear, and filth—and the zoonotic hazards—can hardly have been greater then than now.

This hypothesis is upheld by the findings of Galton and her co-workers in Florida,[73] who demonstrated the conveyance of infection from mildly ill and healthy carrier animals to normal animals during the enforced congestion of their existence in sales barns, in transport vans or trucks, and in holding lots, before slaughter. Rectal or caecal swabs from hog carcasses showed that up to 80% were infected with salmonellae, although the incidence of positive rectal swabs among 374 hogs on 28 farms averaged only 7%. Again, from roughly 1200 cattle on 7 dairy farms, only 1.7% of positive specimens were obtained; whereas faecal cultures taken from 147 cattle immediately after slaughter showed 12% to be *Salmonella*-infected. The same authors noted various mechanisms whereby *Salmonella* pollution was spread in and around abattoirs, for example, by equipment

such as dehairing machines carrying pollution to carcass skins, so that evisceration and cutting operations were often performed in contaminated areas. Further, they reported marked but unelucidated differences in the occurrence of salmonellae in sausage-meat from several local abattoirs, as well as between products of local and regional abattoirs and of producers with nation-wide distribution. In other words, their findings do not necessarily hold for the rest of North America, or for other parts of the world; the principles they illustrate are nevertheless relevant everywhere.

Evidently, the public health hazards of any slaughtering-place and its environment, so colourfully portrayed in the Sanitary Act of Richard II almost 600 years ago, are liable to be magnified in certain respects in the large present-day abattoir. Indeed, it would be hard to devise a more effective means of pooling animal sources of salmonellae, of providing abundant opportunities for ante- and post-mortem transfer of these organisms, and of furnishing excellent media for maintaining their viability and promoting their proliferation. In North America, where packing-plants tend to operate on a massive scale, and at rather frenzied tempo, these hazards would seem to be especially great. However, the largest outbreak of meat-borne salmonellosis ever recorded (due basically to faulty abattoir operations) occurred in Sweden, in the summer of 1953. The responsible agent, *S. typhimurium*, was traced to a large slaughterhouse in Krönöberg County, where a labour controversy had resulted in a great accumulation of animals for slaughter, thus overtaxing the capacity of the slaughterhouse for normal sanitary operations. Other factors contributing to the resulting 7717 notified cases, with 90 deaths, were: insufficient cooling of meat held in storage, owing to failure of the plant's refrigerating facilities; and an unusually high outdoor temperature — 84°F (29°C) — which favoured rapid growth of bacteria in the meat during its processing, storage, transport, and holding in retail shops and homes.[135]

Extensive epidemics can likewise develop because of the inadequate concern for general sanitary precautions, and particularly for rodent control, which the smaller commercial establishments are apt to display, even when operating under government supervision. In the summer of 1946, an extensive outbreak of meat-borne gastro-enteritis caused by *S. typhimurium* occurred in England, in the county of Essex. Some 3000-4000 cases developed among the customers of every retail butcher's shop in the affected area. Fortunately there were no more than 3 deaths. The source of the outbreak was probably one or two infected pigs, sent for slaughter because they were not thriving. Contamination of many other carcasses resulted because of very unhygienic conditions in the slaughterhouse, including the use of wiping cloths which were dipped in a common bucket of water, without ever being washed or boiled. Flies abounded, while the slaughtermen's techniques were rudimentary and their accoutre-

ments filthy. Although the prime vehicle of infection was raw meat, corned beef became a secondary vehicle as a result of the two types of meat being handled together in butchers' shops.[20]

Rats were a negligible factor in this epidemic, but the possibilities of human salmonellosis arising from lax rodent control are made clear in a recent report from the Nottingham area of England. Over the period 1949-54, 11 different types of salmonellae were isolated from between 6.4% and 40% of groups of rats, totalling 183, killed in a butcher's by-products factory. By contrast, only 2 types of salmonellae were found in 4.4% of 518 rats killed in several other sorts of factory premises. The conclusions were that a large variety of salmonellae were brought into the factory in the offal; that delay in processing the offal led to multiplication of salmonellae therein, as well as to an increase in the rat population; that the rats thus became readily infected; and that conditions favoured transmission of salmonellae from rat to rat, with consequent re-infection of the offal by the rats.[134] Incidentally, the unwarranted use of *S. enteritidis* cultures as rodenticides may lead to human salmonellosis through pollution of meat by rodent excreta.

There are also dangers inherent in small-scale slaughtering, often by private enterprise, which is more characteristic of some European and Asian countries. Amateurs are apt to overlook or ignore abnormalities, while incompetent techniques of handling even healthy carcasses can prove disastrous. For instance, in a rural district of Holland, meat from a healthy, home-reared pig was consumed in the form of brawn and raw sausage by 10 families. Paratyphoid fever developed in 32 persons, of whom 2 died. The evidence suggested the likely source of infection to be the alimentary canal of the pig, from which salmonellae were transferred to the meat during the cleaning of the intestines.[98]

More serious risks stem from the willingness of meat inspectors in certain countries to release for human consumption the carcasses of emergency-slaughtered animals. In the area around Munich alone, from 1914 to 1931, 9 epidemics of salmonellosis, involving a total of 503 persons, were traced to such sources, and accounted for more than half of all cases of acute enteritis reported during this period.[177]

Circumstances such as these partly explain the relatively high morbidity-rates from human salmonellosis in the British Isles and continental Europe. Other contributory factors are discussed on pages 60-69. Presumably, the incidence in the USA would be much higher than now appears, were it not for this remarkably carnivorous nation's culinary and dietetic habits, which on the whole demand proper refrigeration of meats during storage, and seldom favour raw or inadequately cooked sausages and other prepared meat products.

In the last analysis, meat which has been sufficiently cooked, and then served hot, rarely if ever transmits infection to the human consumer. The infallibility of this assertion hinges, of course, upon the sense of the phrase " sufficiently cooked ". If it be taken to signify " heated enough to ensure destruction of all viable micro-organisms and helminthic parasites ", then the claim is valid enough for present purposes, since we are not concerned here with the possible survival of heat-resistant spores or with the persistence of preformed toxins. In other words, the transmission of a zoonotic salmonellosis through the ingestion of any vehicle, whether it be meat, eggs, or milk, presupposes insufficient exposure of this foodstuff to heat.

There are obvious risks inherent in the custom, prevalent in many parts of the world, of consuming certain forms of meat uncooked. In addition, there is a general tendency to over-estimate the permeability to heat of large masses of meat. An " underdone " beefsteak or joint is often deliberately (and safely) eaten, but the outer integuments of a large roasting turkey may give very misleading clues to the temperatures reached in the deeper muscle layers, the liver, or the bone-marrow. In 1941, in the USA, 238 inmates of a mental hospital fell ill, and one of these died, after a Thanksgiving Day turkey dinner. *S. typhimurium* was isolated from the faeces of 36% of the cases. Bacteriological and epidemiological evidence pointed to the turkey or its dressing as the probable vehicle.[153] Although the thermal death time of *S. typhimurium* is not high (less than 30 minutes at 60°C), the temperature reached at the centre of hams and other meats, even after prolonged boiling, often does not exceed 60°-70°C, and may not reach this range in the course of frying or roasting.

Another instructive outbreak, affecting at least 32 persons, occurred in 1947 in Shropshire, England,[113] the vehicle being beef sausages prepared from low-grade or casualty cattle. The organism responsible was *S. dublin*, which may be present in the faeces of up to 10% of healthy cattle.[178] Hygienic conditions at the abattoir were very conducive to contamination of carcasses by organisms of faecal origin. Some of the victims had eaten raw sausages, and furthermore, it was shown that *S. dublin* could be recovered from experimentally inoculated sausages even after they were gently fried for 15 minutes. Sausages are obviously an important potential vehicle of human salmonellosis ; and it seems peculiar that *S. dublin*, despite its predilection for bovine habitats, should have been rarely implicated in such occurrences as that reported in 1938 from South Africa, in which 10 Africans became infected with this organism through eating undercooked meat from a diseased calf.[99]

Control. The above examples of zoonotic salmonelloses were so selected and presented as to indicate the chief modes of promoting and preventing conveyance of these infections to man, and there would be

little point in listing here the detailed precautions suited to various sets of circumstances. Besides, standards and devices which prove workable in one country may be impracticable in another. Nevertheless, certain principles of control, meriting recapitulation, are clearly applicable to each of three distinct stages of the *Salmonella* transmission sequence.

First, since by definition our present concern is with animal pathogens transmissible to man, the strongest possible efforts should be made to reduce the morbidity-rates from salmonellosis among domestic animals and livestock. As always, prevention is far easier, and in the long run much cheaper, than cure. Sound animal husbandry practices, such as careful selection of healthy stock, proper design of barns and pens, good drainage of pasture, avoidance of overcrowding, and minimization of fly and rodent vectors, will be amply repaid. Intermingling of cattle and pigs with chickens, ducks, and turkeys should be avoided, since poultry constitute perhaps the most important reservoir of *Salmonella* infection among domestic animals. When obvious disease strikes a herd or flock, veterinary advice should be sought, and if slaughtering is indicated, this should be promptly and thoroughly carried out. In the light of past experience and present knowledge, to approve the carcasses of such animals for human consumption exposes intermediate handlers and ultimate consumers to undesirable risks.

Secondly, healthy animal carriers of salmonellae embody dangers of a similar but more elusive order, which can be defeated only by widespread recognition of the potential infectivity of animal excrement. This would entail the introduction of improved sanitary practices, and the adoption of higher standards of personal hygiene in all handling of live or dead animals, analogous to the habits, customs, and taboos respecting the avoidance of contact with human faeces long inculcated (though not uniformly practised) in most civilized communities. Since the average present-day slaughterhouse, large or small, offers multiple opportunities for the interchange of organisms of intestinal origin among animals, and from these animals to human handlers, special attention should be devoted to reforms in slaughterhouse methods and standards, including the antecedent transport of animals from market, and the subsequent conveyance of carcasses to retail butchers. The powerful dairy industry has accepted far-reaching reforms in many countries: the meat industry can well afford to do likewise.

The foregoing measures are essential for the eradication of zoonotic salmonelloses, but are redundant in the control of infections conveyed by meat polluted with salmonellae of human origin. Indeed, this is the sole justification for considering these two kinds of human salmonellosis separately; for it is readily conceded that epidemiologically different

kinds of salmonellosis may be clinically and bacteriologically indistinguishable. In any event, once meat infected or polluted with salmonellae has reached the retail butcher's shop, the same basic control measures become applicable, regardless of the source of these organisms.

Thirdly, the principles underlying proper temperature control need to be more widely disseminated. No matter whether meat at the retail market or in the consumer's kitchen be superficially polluted or deeply permeated with salmonellae, its infectivity for man will depend partly upon the serotype involved,[137] and partly on the number of viable pathogens present in a given portion at the time of its consumption. Since meat is an excellent culture medium, its bacterial population will be determined largely by the temperatures at which it is kept. The importance of storing meat at refrigerator temperature is generally appreciated from the standpoint of delaying spoilage ; but less well recognized is the fact that the appearance and odour of meat are not necessarily altered by the presence of pathogens ; and that there are important public health as well as economic advantages in the artificial cooling of meat. Unfortunately, household refrigerators are relatively uncommon except in North America ; in some countries, meat is often deplorably exposed to atmospheric temperatures in butchers' display windows, as well as in homes. At the other end of the temperature range, the importance of subjecting all meat to thorough cooking before consumption can hardly be over-emphasized. There is need for indoctrinating chefs and housewives as to the relatively low temperatures which may prevail towards the centre of a mass of meat even after lengthy roasting, frying, or boiling.

The intricacy of the web linking man with the animal kingdom is well manifested in the ramifying epidemiological pathways followed by the salmonellae in this group of zoonoses. Obviously, salmonellosis cannot be overcome easily. Eventual control can be secured only if physicians and health officials, veterinarians and wild-life experts, farmers, industrialists, and the general public, work co-operatively towards this common goal.

Shigellosis

The shigellae, though primarily enteric pathogens, differ from the salmonellae in being very seldom implicated in animal infections. The belief that under natural conditions they are never pathogenic for animals, however, has had to be modified in recent years. The increasing use of monkeys in laboratory work has brought to notice their liability to enteritis, which has not infrequently proved to be due to *Shigella flexneri*. Moreover, experimental feeding of large doses of dysentery bacilli to rhesus monkeys and cats may provoke dysenteric symptoms. These observations have

little direct bearing upon meat-borne infections, but they do suggest that in some circumstances other animals, used as food for man, might become infected by these organisms, or at least excrete them. That this is no longer a mere possibility appears to have been demonstrated by a recent report from the Belgian Congo, describing the isolation of *S. sonnei* from the bone-marrow of a 2-month-old calf which died without symptoms.[43] The public health significance of such a finding is self-evident.

Meat-borne Helminthic Zoonoses

According to Stoll,[197] the number of helminthic infestations afflicting mankind in " this wormy world " is somewhat greater than the human population. Only a small proportion of the more than 2000 million presumed helminthiases are acquired directly by ingestion of meat ; but world totals, tentatively calculated at 27 million cases of trichinosis, 39 million of beef tapeworm, and 3 million of pork tapeworm, present a serious challenge to meat hygienists and epidemiologists, as well as to parasitologists. An estimated 100 000 cases of echinococcosis, deriving indirectly from meat, should be added to these figures ; for certain herbivores with hydatid disease can convey this infestation through their meat or offal to some species of Carnivora, whose faeces may then relay the infection to man.

Trichinosis

Mode of infection. Trichinella spiralis is a small nematode with an exceptionally wide range of potential hosts, comprising more than 25 mammalian species, including man. The parasite's lack of host specificity, and its ability to complete its life-cycle within the body of a single host, help to compensate for the absence of any free-living phase, but this obligatory parasitism, together with the comparative lability of the larvae (encapsulated within skeletal muscle), render the control of human trichinosis *theoretically* simple.

The encysted larval form of this parasite was first recognized as a " singular animalcule " in human muscle by Sir James Paget in 1835, while dissecting cadavers as a first-year medical student in London.[165] Paget, commenting on these larvae (resembling small spicules of bone, and dismissed by previous observers as of no consequence), said " We can hardly imagine a single body to afford sustenance to some millions of such creatures, however minute, without some visible effect ". A quarter of a century later, Zenker demonstrated that trichinae could cause illness fatal to man in a few weeks.[225]

Although Leidy noted in 1846 an apparently identical parasite in pork, nearly 50 years elapsed before the observations of Mark shed light on the main source of the porcine infestation in the USA. He showed that 13% of garbage-fed hogs from the Boston area were infected, whereas only 2% of grainfed ones from near Chicago were infected. He also found a negligible incidence among hogs fed on cooked kitchen garbage, while those fed on uncooked kitchen garbage and slaughterhouse refuse had infection-rates of up to 63%. Thus, swine were revealed as possible sources of human trichinosis over a century ago, and an effective means of reducing this hazard has been known for more than 60 years. Yet the disease persists as a serious public health problem in the USA, mainly owing to the continued practice in some areas of feeding uncooked garbage to hogs. As recently as the end of 1953, it was estimated in this country that from 5% to 15% of hogs fed raw garbage were trichinous, while less than 1% of grain-fed animals were infected.[82]

Human trichinosis is confined to those parts of the world where food regulations and customs permit the consumption of raw, inadequately cooked, or improperly cured meat, especially pork. In tropical and oriental countries, where meats are usually cooked thoroughly, the disease is practically unknown, and it is very rare among orthodox Jews and Mohammedans who disdain pork. In many European countries, including Germany (where trichinosis was prevalent about a century ago) outbreaks nowadays occur only sporadically; but in Austria, northern Italy, Czechoslovakia, Poland, and Russia this parasite apparently remains a fairly frequent cause of trouble. Trichinosis has seldom been reported from South America, and seems to be unknown in Australia. At present—although one day this geographical immunity may prove to be more apparent than real—to all intents the disease is confined to the northern hemisphere.

Whereas trichinosis is fairly common in Mexico, and is probably less uncommon in the settled parts of Canada than is generally recognized,[193] it is more prevalent in the USA than in any other part of the world. An estimated 1 in 6 inhabitants of that country (roughly 25 million persons) harbour trichinae, which would entail the development of some 350 000 new infections annually. Further, it has been calculated that clinical symptoms would be displayed by 4.5% of the infected, that is, by 16 000 persons each year, a much larger number than the 1942-51 yearly average of 336 reported cases.[133]

Some authorities may question the validity of these figures, but the undisputed main source of trichinosis in the USA is insufficiently cooked pork. Although the over-all incidence of trichinous infection in swine in that country has declined considerably in the past 50 years, recent surveys indicate that of 60 million hogs annually slaughtered, 1.5%, or nearly one million, are infected with trichinae. The extent of the resulting

infection hazard is emphasized by the claim that the average American consumes nearly 200 meals of trichina-infested pork during his lifetime; and of course trichinosis may develop if the larvae be viable in any one of these servings of pork.[34] As might be expected, epidemics tend to occur among German and Italian communities, and also among farmers in sparsely settled areas, who like to eat raw or insufficiently cooked pork. Moreover, trichinosis is apt to display a seasonal incidence, with peaks in winter, especially during the Christmas and New Year holidays, when home- or farm-slaughtered pigs are consumed locally.[81]

The domestic pig is by no means everywhere the main source of human trichinosis. The wild boar and other game animals in Europe, and bears in the USA and Canada, have been implicated as vehicles, often to hunters and their friends who have feasted on such flesh insufficiently cooked. Moreover, in the Arctic, where pigs are not found, trichinosis is a major public health problem. Throughout the circumpolar regions, including Siberia, land carnivores and marine mammals are liable to be heavily infested with *Tr. spiralis*. The Arctic explorer Stefansson first suggested in 1914 that trichinosis rather than ptomaine poisoning might have caused fatal illnesses ascribed to eating the meat of the white whale.[194] Twenty years later, Parnell found *Tr. spiralis* in the muscles of the polar bear and the arctic fox in north-east Canada, and warned that so-called ptomaine poisoning among Eskimoes might be due to trichinosis.[166] In 1948, Stefansson relayed a brief report that during the war, a party of 8-10 persons manning a German weather station on Franz Josef Land had become ill after eating polar bear meat infected with trichinae. Evacuated by air to Oslo, some of the victims remained hospitalized for months.[195] This is probably the first accurately identified outbreak of Arctic-acquired human trichinosis on record. But the full gravity of this problem was brought home by an extensive epidemic in west Greenland in 1947, which involved some 300 natives, of whom 33 died. Walrus meat was apparently the main cause, with the flesh of dogs and white whale as possible subsidiary sources of infection. Of 66 sledge dogs examined, 46 (70%), and of 19 polar bears, 6 (30%), were trichinous.[207]

After this episode, investigations were launched in the North-West Territories of Canada and in Alaska. About 50% of the native population of Southampton Island gave a positive skin test for trichinosis;[16] while at Wainwright and Barrow 27% of adults reacted positively.[14] Wherever found, the polar bear seems very liable to be infected, but the Eskimo dog, and to some extent other land and marine mammals of these regions, may also harbour this parasite. Trichinosis is presumably a long-standing zoonosis of the Arctic, for such a widespread footing could hardly have been established recently. Indeed, only the peculiar life-cycle of this worm could have enabled it to survive so inhospitable a climate.[32]

Control. The control of trichinosis logically includes measures designed (1) to prevent spread of infection to swine, (2) to reveal the presence of infection in swine carcasses, and (3) to render infected meat innocuous.

(1) Swine undoubtedly become trichinous chiefly from being fed uncooked garbage containing infected pork scraps. Since rats may abound in such refuse, and are occasionally eaten by pigs, they have been blamed as vectors; but though these rodents are very prone to trichinous infection, and should be kept away from piggeries, their role as a primary reservoir of porcine trichinosis seems to have been exaggerated. The greater prevalence of this zoonosis in the USA than anywhere else in the world seems clearly due to the conspicuous wastefulness which makes raw garbage in that country a cheap and nutritious form of pig-swill. In many other countries, garbage is either incinerated or subjected to salvaging processes; while in England and Canada, if garbage is to be fed to swine, it must first be boiled for 30 minutes. In the USA, Federal regulations now require the cooking of all garbage for hog feeding which is to traverse State lines, and it seems likely that before long the combined advice of public health and veterinary experts will persuade a few recalcitrant State authorities to enact and enforce the necessary legislation.

(2) Ordinary inspection of hog carcasses and pork products is of very limited value in trichinosis control; and in any event, small slaughterhouses frequently undergo no inspection whatever. In Germany and some other European countries, microscopic examination by means of the "compressorium" or trichinoscope is applied to every pig slaughtered, and all animals found infected are condemned. This system is considered unworkable in the USA on the grounds that it is too costly; that the samples examined may be unrepresentative of the whole carcass; that to stamp pork as having passed microscopic examination gives rise to a false sense of security; and that even if such measures were thoroughly carried out by Federal Government inspectors, nearly one-third of all pork produced in the country would not come under their scrutiny.[34] A further cogent argument is that trichinoscopic examinations are much less sensitive than the more time-consuming peptic digest method. In a recent study of more than 3000 hogs originating in corn-belt States, trichinae were present in only 0.6% of diaphragm samples subjected to the digestion procedure. No trichinae were detected in routine press preparations of the infected diaphragms. In parallel studies of about 1500 samples from garbage-fed hogs from Atlantie coast States, the digestion method yielded 11.5% positive, while press preparations showed only 5% positive.[189] Such findings seem to reduce the economic validity and the public health usefulness of the trichinoscopic examinations routinely employed in certain European countries with low incidences of human and porcine trichinosis.

(3) Fresh pork may be rendered innocuous by exposure to sufficient heat or cold ; by thorough salting, curing or smoking ; and by irradiation. The effects of low temperature on the viability of *Tr. spiralis* larvae in raw pork have been intensively studied. In the USA, current Federal regulations pertaining to the " low-temperature treatment " require that cuts of pork not over 6 inches (15 cm) thick be exposed to 5°F (–15°C) for 20 days ; to –10°F (–23.3°C) for 10 days ; or to –20°F (–29°C) for 6 days. Larger pieces, of course, require longer exposures or lower temperatures. A temperature of –36°F (–38°C) maintained for only 2 minutes at the centre of a piece of trichinous meat will kill the larvae.[82] Exposure of all pork to such low temperatures is at present too costly and impractical for general application, but its adoption by more meat distributors may be hastened by the growing popularity of domestic deep-freeze units—a trend which may help in itself to lessen the incidence of trichinosis.

Adequate cooking is the consumer's principal protection against trichinosis, in civilized and primitive communities alike. *Tr. spiralis* is relatively heat-labile, its upper thermal death point being 131°F (55°C). In their processing methods, the larger packing plants in the USA and Canada must follow Federal Government regulations bearing on the salting, curing, smoking, and cooking of meat products, certain of which are designed specifically as safeguards against trichinosis. The minimum temperature reached at the centre of prepared meats containing pork, such as hamburgers and frankfurters, must be 137°F (58.3°C). Likewise, in the smoking of ham, this same internal temperature must be attained. For restaurants and households using fresh pork, the safest precaution is probably to boil smaller portions of meat for 30 to 35 minutes per kg, and larger cuts for twice as long. A rough guide is afforded by the appearance : an adequately fried chop or cooked sausage will appear white throughout, without trace of pink.

Gamma-irradiation of pork by exposure to X-rays, cobalt-60, or packaged atomic fission material, may well become the future method of choice for sterilizing larvae of *Tr. spiralis*.[82]

In primitive societies, such as the Eskimoes, trichinosis control presents extremely difficult problems. In the first place, when an Arctic animal is slaughtered, a relatively small number of persons are apt to consume rather large quantities of its flesh, without those factors of delay and dilution which mitigate the dangers in manufactured meat products. (Sausages are often composed of meat particles originating from numerous animals, only one of which may be a trichinous pig.) Secondly, the Eskimo prefers meat parboiled, and on festive occasions often takes his protein raw. He can be taught the necessity of cooking his food, but when fuel is scarce, time short, and hunger rampant, caution will be thrown to the winds.

Similarly, trichinosis can become one of the hazards of war. Apart from the general relaxation of meat hygiene measures, affecting chiefly the civilian population, those on active service face special risks of meat-borne infection. For example, during the Second World War, a small German commando unit halted for the night on the Polish frontier, and appropriated a pig from a near-by farm. The meat was eaten raw, partly out of hunger, and partly to avoid advertising their presence by lighting a fire. They were all put out of action by trichinosis.[128]

Taeniasis

Mode of infection. The beef tapeworm, *Taenia saginata*, requires a very special set of circumstances for completion of its life cycle. Leuckart in 1861 first demonstrated the connexion between this cestode in man and the bladder worm of calves or " measly " beef. The worm grows to maturity solely in the human intestine and sheds its eggs therefrom, while only cattle can serve as intermediate host for the larval or cysticercal stage. In other words, it is essential to the development of an adult tapeworm that a cow should eat grass contaminated with ova from a human intestine, and that parts of this cow containing the larvae (*Cysticercus bovis*) should be eaten more or less raw by a human—whose faeces must in turn reach a cow pasture if the cycle is to continue. Despite such specific restrictions, *T. saginata* infestation is apparently commoner and more widespread than trichinosis, and is over thirteen times as prevalent as taeniasis due to *T. solium*, the pork tapeworm. These disparities presumably derive from the greater number of humans who relish underdone beef, as compared with those who consume raw or inadequately cooked pork.

The USSR with 19 million cases, and Africa with 12 million cases, are the land areas to which the largest numbers of *T. saginata* infestations have been ascribed.[197] Asian countries, particularly heavy beef-eating Moslem communities, account for another 6 million cases. In the British Isles and most parts of Europe, the disease occurs only sporadically, but is probably less rare than the statistics suggest.[5] In Australia, some 20 years ago, the beef tapeworm was found to have a very high incidence among Syrian-born residents of the State of Victoria.[170] The parasite is fairly common in South and Central America and in Mexico, and is the most frequently encountered large tapeworm in the USA. In most countries, the lower economic groups are more liable to infection, but in some parts of the USA it has been identified in well-to-do professional groups, possibly because they can afford steaks frequently, and like to eat them rare.

Maintenance of the life-cycle of the pork tapeworm, *T. solium*, requires an analogous man-pig-man relationship. When swine ingest foodstuffs

polluted with human excrement containing *T. solium* ova, the eggs develop into larvae (*Cysticercus cellulosae*) in the pig muscles. The flesh of such animals, eaten as underdone pork or raw sausage, may then become the source of adult tapeworms in the human intestine. The comparative rarity of *T. solium* infestation is fortunate, because the pork tapeworm is more dangerous than the beef tapeworm, owing to a propensity for developing cysticerci in human tissues outside the musculature. Its ova, when ingested by man, may develop into larvae in the human brain instead of in porcine muscle. Nearly one-half of the known cases of this taeniasis occur in Asia. The condition is uncommon in the USA and Canada, but is less rare in Mexico and countries to the south.

Control. The life cycle or chain of transmission of these helminthiases can be severed by (1) prevention of insanitary disposal of human faeces in or near cattle-raising or swine-feeding establishments, (2) careful inspection of cattle and hog carcasses in abattoirs, and (3) adequate cooking of beef and pork in restaurants and homes.

(1) Easily accessible and well-designed privies should be provided near cattle-lots and piggeries. Their use should be urged upon employees by education and enforced by regulation, with loss of employment as the penalty for non-compliance. A few careless individuals, infected with *T. saginata* or *T. solium*, may discharge ova by habitual or casual defaecation on pasture land or feed lots, in drainage ditches, and even in silage tanks.[200] Feeding animals with raw vegetables grown on soil fertilized with human faeces could have the same result.

In some parts of the world, local circumstances and customs may be unadaptable to such restrictions. For instance, in Australia a less stringent attitude towards infestation with *Cysticercus bovis* has been advocated, as it was shown that the larvae seldom live more than two or three months, and begin to calcify within six months ; and further, that cattle once infected remain immune to re-infection for a few years at least.[170] Since raw sewage was often used for farm irrigation in that country, it was recommended that calves should be intentionally exposed to heavily polluted areas to ensure early infection, but should not be slaughtered for 2-3 years thereafter, by when even calcified cysts would have become absorbed. Similar arrangements were proposed for Syria, and parts of Africa and India, where *T. saginata* infestation has been so prevalent and sanitary conditions so primitive, that oxen could hardly be prevented from grazing on pastures, or drinking water, contaminated with the ova. However, this system merely interposes an immunity barrier of uncertain durability and efficacy, and seems open to several theoretical objections and operational abuses.

(2) " Measly " beef or pork has been recognized for centuries as unfit for human consumption. *Cysticercus bovis* in cattle, and *C. cellulosae*

in swine, are—unlike trichinae—readily visible to the naked eye, and tend to concentrate in the heart region, so that thorough inspection of every carcass would probably eliminate most infected beef and pork from the public market. Nevertheless, no part of the world can guarantee that all its publicly sold meat has been properly inspected ; and private sales would continue surreptitiously even if banned. Moreover, in some countries, the infestation may be so widespread as to render measles-free beef economically difficult to procure. Such a situation inevitably tends to reduce the stringency of rejection criteria, although even slight relaxations may have marked public health consequences. For example, in 175 experimentally infected animals, the average distribution of cysticerci between heart, masticatory muscles, tongue, and diaphragm was found to be in the ratios of 8 : 4 : 1 : 1. Hence it was deduced that probably 100% of animals containing 4 or more cysts in these sites would have their infestation detected by complete examination of the heart alone ; whereas if no more than from 1 to 3 cysts were present in these sites, only 88% of infested animals would be identified by complete examination of the heart and masticatory muscles.[170]

In the USA, Federal meat inspection figures disclose roughly 0.1% of cattle infected with *C. bovis*, but the incidence may be much higher in certain areas. For instance, cattle fattened in the Salt River valley of Arizona showed an average of 3% infection, most of it traceable to one ranch with an infection-rate of 12%.[200] Present policy in this country is to condemn extensively infected carcasses. If only slight infection be apparent, all visible cysts must be removed and condemned, and the remainder of the carcass may be released for human food, provided the destruction of hidden cysts be ensured by heating, cold storage, or pickling processes.

(3) The upper thermal death point for cysticerci is the same as for trichinae, that is, they are killed quickly at 131°F (55°C). Therefore, precautions similar to those already advocated against trichinosis should be taken to ensure thorough cooking of beef and pork. Cold storage or pickling for at least 21 days, or exposure for 6 days to a temperature of not more than 15°F (–9.5°C), will also effectively destroy the cysts.

Since man is the definitive host and the originator of the re-infection cycle in these zoonoses, practising physicians can contribute importantly to public health through detecting and eliminating taeniasis in their patients. However, this diagnostic and therapeutic approach to the problem of prevention is relatively expensive and complicated.[170]

The development of *C. cellulosae* in man is best averted by observance of elementary personal hygiene, so that ova possibly present in his own faeces are not ingested ; and also by avoidance of uncooked foodstuffs which

are liable to human faecal pollution, such as raw vegetables grown on land fertilized with sewage.

Echinococcosis

Mode of infection. Whereas *T. saginata* and *T. solium* may attain a length of several metres in the human intestine, the parasite responsible for human hydatid disease, *Echinococcus granulosus*, is only 3-6 mm long. Its optimum definitive host is the dog, but alternative habitats are the intestinal tract of related Canidae, such as the fox and wolf, and (rarely) of certain Felidae, such as the lion and puma. Domestic and wild ungulates or ruminants, for example, the sheep, cow, deer, and moose, are the usual intermediate hosts for the larval stage, or hydatid, which develops in their lungs or liver following the ingestion of ova from an echinococcus-infested carnivore. This hydatid may continue to grow slowly but almost indefinitely, forming a large tumour-like cyst. The life cycle of the parasite is normally completed when the hydatid-infested viscera of a ruminant are consumed by a suitable carnivore.

Man plays only an incidental role, as a blind-alley intermediate host, in the life-cycle of *E. granulosus*. Ova ingested through fingers or food polluted with dog faeces may develop into a hydatid cyst of the human liver or lungs—the cycle usually stopping there, since carnivores seldom have any chance to eat such infected human viscera. Although human hydatid disease is not acquired directly by consumption of infected meat, it earns a place in this review on two counts : first, because meat, among other foodstuffs, can serve as a vehicle for echinococcus ova ; and secondly, because dogs generally become infected through close association with man in his quest for supplies of meat.

Echinococcosis has been heavily endemic in certain sheep-raising parts of the world, such as Iceland, New Zealand, southern Australia, and certain countries of South America, where intimate sheep-dog-man relationships prevail. Dramatic reductions in the incidence of the human infection have been achieved in Iceland,[56] and in Australia, by preventing canine infection. Basically, this involves education of the public against feeding the viscera of slaughtered sheep and cattle to dogs. In endemic areas, stray dogs should be impounded and destroyed ; and small abattoirs, to which dogs have readier access, should be consolidated into larger units. Other measures, which contributed to the successful campaign in Iceland, include the annual administration of anti-helminthic drugs to every dog, and the early slaughter of lambs for market, before any hydatids have matured and become infective. Through such means, the younger age-groups among Icelanders have become practically free from hydatid disease, whereas a century ago one-seventh of the population was infected.

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In recent years, the existence of a sylvatic form of echinococcosis has been demonstrated among the wild carnivores and herbivores of northern Canada.[148, 261] *E. granulosus* is widely distributed in wolves, whose faeces seed the ground with tapeworm ova. These eggs, ingested by grazing herbivora, develop into hydatids in their viscera. When wolves or other predators kill a moose or caribou, and eat the infested viscera of such intermediate hosts, the life cycle of the parasite is completed. Sylvatic echinococcosis has probably existed unobtrusively for many years, if not centuries, in northern Canada, as well as in other boreal regions, including Alaska, Scandinavia, and Siberia.[175] Whenever these areas become inhabited by men and their dogs, the disease looms as an important public health problem. Human infection is seldom acquired directly from the wild carnivora, but if dogs have access to the hydatid-infested lungs of caribou and moose, a subsidiary cycle is started with man as potential intermediate host. When the dogs excrete *E. granulosus* ova in their faeces, human hands become polluted therewith, and the ova are ingested and in due course develop into hydatids in the lungs, liver, and sometimes other parts of the human body.

Many aspects of the epidemiology of echinococcosis remain to be clarified, but it seems certain that there are alternative cycles to those already mentioned. For instance, in Lebanon a high percentage of camels have been found infected, while in Lapland and other parts of northern Scandinavia hydatid disease is closely associated with reindeer management. Other reservoirs have been identified which admittedly present few risks to human health. In Alaska, red and arctic foxes are commonly infected, presumably from feeding on ungulate carcasses which they happen across. Again, in Siberia, and on St Lawrence Island in the Bering Sea, an immunologically distinct species of *Echinococcus* appears to have been discovered, in which voles of the genera *Microtus* and *Clethrionomys* serve as intermediate hosts for the larval stage.[175] There is also some evidence (based on variations in sensitivity of human cases of hydatidosis to different Casoni skin-test antigens), which suggests that infestations originating in northern Canada may be allergenically dissimilar to those contracted in southern Australia. Finally, in certain parts of the world, notably Bavaria, the Tyrol, and Siberia, a malignant, "alveolar" form of hydatidosis affecting man has been attributed by some authorities to the larvae of a distinct species of *Echinococcus*.[100]

Control. Control measures obviously include strict attention to personal hygiene, especially by dog handlers, who should thoroughly clean their hands before eating. Also, efforts should be made to protect dogs from infection, by educating Indians, Eskimoes, and similar populations, as well as trappers, prospectors, and explorers, to awareness of the dangers of feeding uncooked moose and caribou viscera to their dogs. Among some

tribes, taboos already exist which might be rendered more effective by rationalization. A useful subsidiary measure, where feasible, is the regular and official treatment of dogs with taeniacidal drugs, in order to eradicate or at least diminish regional canine reservoirs of echinococcosis. The parasite's cycle among feral fauna could perhaps be curbed by slaughtering programmes, but only at prohibitive cost.

Rare Meat-borne Zoonoses, possibly acquired by Ingestion

Besides those species mentioned above, many other helminths may infect man occasionally (but not primarily), through the ingestion of polluted foodstuffs, including meat. The latest parasitology texts should be consulted for examples of such contingencies. The remainder of this section will be devoted to brief consideration of a few zoonoses caused by miscellaneous parasites, which are probably meat-borne, and whose epidemiology seems sufficiently peculiar to warrant mention here. The examples chosen are toxoplasmosis, sarcosporidiosis, and intestinal myiasis.

Toxoplasmosis

Toxoplasma gondii, the type species of the genus *Toxoplasma*, was discovered nearly 50 years ago in a small North African rodent called the gondi, by Nicolle & Manceaux.[159] These parasites remain in many respects mysterious. Their systematic position is still unsettled, though they should probably be classed as Protozoa. They parasitize a wide range of mammals and birds, and seem able to invade most human and animal tissues. Little is known about the mode of transmission of toxoplasmosis to man, except that no arthropod vector has been implicated epidemiologically. Recently, it has been postulated that human toxoplasmosis may be contracted in a fashion very reminiscent of trichinosis—that is, through eating inadequately cooked pork, the swine having become infected by feeding on other swine, or on rodents, particularly rats. Preliminary results of efforts to verify this hypothesis experimentally showed that *Toxoplasma* infection was transmitted between swine and rodents when either animal species was fed artificially infected tissue from the other. Pigs likewise became infected from feeding on swine offal.[216] Since murine and porcine toxoplasmosis are known to occur naturally, the possible implications of the above findings from the standpoint of human disease are evident, and warrant further investigation.

Sarcosporidiosis

Sheep, cattle, horses, and pigs are prone to infestation with parasites of the fairly widespread genus *Sarcocystis*. In a recent investigation in

England, the presence of *Sarcocystis* was demonstrated in the muscles of 31 out of 45 sheep, collected from three different countries.[6] The parasites, whose classification again is uncertain, have an elongated ovoid shape, and range from microscopic dimensions to as much as 5 cm in length. In structure, each parasite consists essentially of innumerable rounded and crescent-shaped spores enclosed in a membrane. They are usually found among striated muscle fibres (less often in unstriated muscle) of mammals, and sometimes of birds and reptiles. A very small number of authenticated human cases of infestation with *Sarcocystis lindemanni* have been reported. In man, the parasite apparently lodges in striped and cardiac muscle, where it generally produces little disturbance. In one proven case known to the writer, migratory local swellings have occurred at irregular intervals in the muscles, accompanied by asthmatic attacks, for a period of 7 years to date.

Since this parasite's usual habitat is the flesh of animals commonly used as human food, infestation in man presumably could occur by the oral route. The possibility that the human disease may be commoner than is now realized could be checked by performing complement-fixation tests for specific antibodies on persons living in areas where livestock has given evidence of sarcosporidiosis.

Intestinal myiasis

Many species of flies of the order Diptera lay their eggs on foodstuffs, including meats. Apparently, dipterous eggs can mature, while unmasticated larvae can survive, in the human intestinal tract, to be passed eventually in the faeces. Until expelled, these larvae may cause abdominal pain, with bloody and mucoid stools. Larvae are sometimes passed repeatedly over long periods ; but of course this points to recurrent ingestion of eggs or maggots rather than to any sort of proliferation within the intestine. *Piophila casei*, the cheese fly, which deposits its eggs on ham, bacon, and other smoked meats, as well as on fish and in old cheese, has been reported quite often to cause intestinal myiasis.[169]

A more serious and complex form of infestation is caused by the larvae of *Porocephalus (Armillifer) armillatus*, an unusual worm-like parasite—a degenerate arthropod—whose primary habitat is the lungs of certain reptiles, birds, and mammals. Human infestation is rare, except among some native tribes in the Belgian Congo, who commonly eat the flesh of pythons. The condition may also be acquired from vegetation polluted with the eggs of this parasite, or by drinking ova in water contaminated with the sputum or excreta of snakes. Larvae are liberated from the ova in the human intestine, penetrate the mucosa, and usually encyst in the mesentery or on the surface of the liver and other abdominal viscera,

where they are normally symptomless. Occasionally, these cysts cause trouble requiring surgical intervention.[83]

INFECTIONS AND INTOXICATIONS CAUSED BY EXOGENOUS (HUMAN AND ENVIRONMENTAL) CONTAMINATION OF MEAT AND MANUFACTURED MEAT PRODUCTS (BACTERIAL FOOD POISONING)

The preceding section has illustrated the many varieties of organisms pathogenic for both animals and man which may cause human illness and even death through the consumption or handling of intravitally infected meat. This final section is concerned with the infections and intoxications liable to be conveyed by meat and manufactured meat products contaminated post mortem with pathogens of human or environmental origin. Certain duplications and inconsistencies, which seem unavoidable in any arbitrary classification, may become apparent here. For instance, although botulism is usually regarded as being caused by exogenous contamination, in meat-borne botulinic episodes the causal micro-organisms may sometimes originate in the tissues or intestinal tract of an animal before or after slaughter. Likewise, in so-called food poisonings with enterotoxigenic staphylococci, or *Clostridium welchii*, although pollution from human hands or from such extraneous sources as air and soil is usually postulated, the actual origins of the agents concerned are often undetermined ; and in these cases the possibility of intravital animal involvement should be considered. In other words, some conditions considered here may occasionally show zoonotic attributes. However, to give full recognition to such minor overlappings entails stretching the definition of the zoonoses to a point where epidemiological features would become obscured.

Again, there is a certain redundancy in the grouping of meat-borne salmonelloses under separate headings, according as the causal organisms are derived endogenously, that is, zoonotically, or are introduced through post-mortem pollution of human origin. Such duplication, illogical though it may be on clinical grounds, seems justified because of different epidemiological patterns and control measures. For while maintenance of proper temperatures at all stages of food preparation and storage should, in theory, avert most meat-borne diseases, supplementary preventive techniques based on specific epidemiology should also be practised. Thus, the main public health objective in the zoonoses is to sever the parasites' chains of transmission from animal hosts to prospective human hosts at their most accessible and vulnerable links ; whereas in the control of non-zoonotic meat-borne infections and toxaemias, safeguards must be directed

mainly against the contingencies of human, atmospheric, and telluric pollution.

The sub-title " bacterial food poisoning " given to this section calls for brief comment. Clearly, any disease for which meat has served as vehicle might be regarded, in a sense, as an example of food poisoning, but a commoner and more restricted usage of this term will be adopted for present purposes. First, the outbreak should be epidemiologically related to consumption of a particular foodstuff by each victim ; secondly, the incubation period and symptomatology of the disease, as well as the nature, mode of preparation, and method of storage of the suspected foodstuff, must be consistent with some degree of proliferation of a known pathogen, or with elaboration of a specific bacterial toxin, in the food before its consumption ; and thirdly, the laboratory findings should confirm, or at least be compatible with, the foregoing prerequisites. Admittedly, some authorities regard even this narrower definition of " food poisoning " as too broad, and would limit the use of the term to intoxications due to *Cl. botulinum* and staphylococci,[3] while others would advocate that the medical profession should abandon use of the terms to the public.[61]

Meat, of course, is an excellent medium for growth of a wide variety of micro-organisms, some of which induce spoilage without directly threatening human health, while others can cause disease and death when ingested by man, without necessarily altering the appearance, odour, or taste of the meat. The methods, both ancient and modern, used in the preservation of meats,[112] are designed to inhibit or destroy all such organisms, but achieve this objective with only limited success, for reasons discussed below. The extent of the failure is made evident in figures showing the incidence of food poisoning outbreaks for England and Wales over the period 1941-53. Table I shows the total numbers of verified outbreaks (each representing two or more related cases in different families) recorded during the years designated, the numbers and percentages of outbreaks ascribed to meat as vehicle, and the numbers and percentages of meat-borne outbreaks attributed to processed or made-up meat products. Over the whole period, of 1782 reported outbreaks in which the vehicle was determined, 1135, or 64%, were ascribed to meat in various forms. Moreover, of this total, 931 outbreaks, or 82%, were traced to processed or made-up meats. The annual percentages were remarkably constant, although it is evident that far more outbreaks were reported annually after 1948. This change resulted from new regulations enacted in 1949, which required medical health officers and public health laboratories to submit detailed reports to the Ministry of Health and the Medical Research Council, respectively.[86] Data received from these sources could be collated and tabulated with fair accuracy, though the reported incidence doubtless still fell short of the true incidence. When the large numbers of familial

episodes and sporadic cases reported to the authorities are reckoned in, with due allowance made for unreported additions to these categories, the annual totals point impressively to the importance of meat as an agent of bacterial food poisoning in England and Wales.

TABLE I. FOOD POISONING, ENGLAND AND WALES, 1941-1953: NUMBER AND PERCENTAGE OF OUTBREAKS INVOLVING MEAT* AS VEHICLE OF INFECTION

Year	Number of outbreaks where vehicle ascertained	Outbreaks ascribed to meat		Meat dishes processed or made-up	
		no.	%	no.	%
1941–48 [67]	191	109	57	90	83
1949 [29]	339	222	65	195	88
1950 [30]	435	268	62	210	78
1951	233	154	66	115	75
1952	274	183	67	150	82
1953 [31]	310	199	64	171	86
Total	1782	1135	64	931	82

* "Meat" includes fresh, canned, processed, and made-up meats, as well as gravy, soup and stock.

A few years ago, this situation was recognized by the Ministry of Food, which launched an inquiry into the conditions of manufacture of meat products from the standpoint of sanitation and public health. Subsequently, a report was published which outlined many ways whereby an astonishing variety of some 65 main products could be mishandled and thus become polluted, with consequent risks of bacterial food poisoning.[85]

In other countries for which relevant data are available, meat and meat products feature less prominently as food poisoning vehicles. For instance, in the USA, of 392 food poisoning outbreaks proven to be caused by a single organism, and reported to the Public Health Service over the period 1945-47, the vehicle was meat or meat products in 127, or 32%.[61] This relatively low rate (only half of that observed in England and Wales) seems less likely to be related to ineffective reporting regulations than to differences in food handling and consumption habits in the two countries.

The chief sources of micro-organisms concerned in these types of meat-borne outbreaks are the human intestinal tract (*Salmonella*, *Shigella*, and related species); the human nose, throat, and skin (*Staphylococcus*); and the soil (*Cl. botulinum*). The various clinical syndromes to which these organisms give rise do not concern us here. The epidemiology of the

commoner forms of meat-borne infections and toxaemias will be reviewed first, followed by brief consideration of a few rarer forms of bacterial food poisoning conveyable by meat.

One of the lively controversies which marked the early decades of microbiological discovery concerned the question whether putrefaction was a cause or an effect of disease. The hypothesis that products of protein decomposition—Selmi's ptomaines—were responsible for certain forms of bacterial food poisoning arose as an offshoot of this controversy. Chemical analyses, along with Bouley's dictum "Tout ce qui pue ne tue pas, tout ce qui tue ne pue pas",* combined to render the ptomaine theory untenable long ago. However, in lay parlance "ptomaine poisoning" dies hard; while even in certain professional circles, until fairly recently, the relatively short incubation periods characteristic of many bacterial food poisoning outbreaks were ascribed to the presence of "toxin" of unspecified origin. Eventually, staphylococcus food intoxication, in which susceptible humans developed acute gastro-intestinal disturbances within a few hours of ingesting foodstuffs containing preformed enterotoxin, was differentiated as a specific entity. A substantial proportion of remaining examples of the so-called "toxin" type of food poisoning are probably *Salmonella* or *Shigella* food-borne infections in which the incriminated food has had opportunities of serving as a nutrient medium for extensive bacterial proliferation.

Salmonelloses

Mode of infection

Food-borne infections caused by *Salmonella* or *Shigella* occur in all parts of the world. A febrile form of gastro-enteritis generally results, with an incubation period ranging from as little as six hours to as much as two or three weeks, according to the host's non-specific and specific immunity mechanisms, the particular species and strain of pathogen involved, and the dosage of organisms ingested with the food. As a rule, the more the pathogen has multiplied in the food before consumption, the shorter the incubation period. For these conditions, Feig [61] urges use of the terms "acute salmonella gastro-enteritis" and "acute shigella gastro-enteritis", in place of salmonellosis and shigellosis, respectively. This terminology has the merit of stressing the salient clinical feature as well as the etiological agent in such food-borne infections, but fails to cover the protean clinical manifestations of salmonellosis caused by post-mortem pollution of meat by organisms as different as, for example, *S. typhi*, *S. choleraesuis*, and *S. typhimurium*. Moreover, the paramount

* "All that smells does not kill; all that kills does not smell."

issues under discussion here are epidemiological, and hence (for reasons already given) re-consideration of the salmonelloses is required.

Since most known representatives of the *Salmonella* genus are potentially infective for man, whose intestinal tract is one of their main harbourages, it follows that in a given community the incidence of meat-borne salmonellosis caused by human faecal pollution will depend upon the following variables : (i) the incidence of salmonellae in the intestinal tract of local food handlers ; (ii) the hygienic standards of such persons, particularly when employed in public eating-places, schools, and other institutions ; and (iii) the prevailing methods of meat usage, storage, and cooking. After these factors have been briefly considered in turn, some examples will be given, and control measures discussed.

(i) Almost every clinical case of human salmonellosis excretes the causal micro-organism from the bowel in variable numbers for an unpredictable period. The duration and extent of this infective phase apparently bears little relation to the severity of the symptoms. The " convalescent " and " chronic " carrier states, long recognized in connexion with typhoid and paratyphoid fevers, can also follow the acute gastro-intestinal syndrome resulting from consumption of meat heavily infected with almost any *Salmonella* species. Moreover, a wide variety of such species have now been identified in persons giving no recent history of acute gastro-enteritis —that is, in so-called " healthy " carriers. These various kinds of carriers, as well as ambulatory, atypical, and unidentified cases of salmonellosis, represent a hidden reservoir of potential food-borne infection. The extent of this reservoir in any given region may be revealed by cultural surveys of faeces from typical groups of food handlers. To be worth while, such surveys must be carried out by competent bacteriologists, using the latest selective media, and should be backed by the assurance of some definite follow-up by the public health authorities.

The *Salmonella* carrier rates noted in different parts of the world have ranged from around 0.3% to over 30%. In other words, assuming roughly the same degree of attention to hand-washing practices, the chances of meat products becoming polluted with salmonellae of human origin are 100 times greater in some communities than in others. Unfortunately, some local authorities have discouraged cultural surveys of food handlers on the grounds that the cost of uncovering a single carrier is unduly high ; while others elsewhere have overlooked results which seemed to implicate too many carriers for control measures to be feasible.

(ii) Even in countries where the visitor faces a 1 : 3 probability that his food would be prepared by a *Salmonella* carrier, a high degree of security could be assured if all food handlers thoroughly washed their hands after defaecation ; but of course in reality such assurance can nowhere be given.

In many public eating-places, the food handler's personal hygienic habits, all too often casual and uninformed, are not noticeably subject to instruction or reprimand from the proprietor, to demands from the customer for more exacting standards of service, or to enforcement of stringent regulations by the health department. The desirable improvements in standards of restaurant and household hygiene depend basically upon education of the public by trained intermediaries, including public health nurses, sanitary inspectors, and health teachers in schools and colleges.

(iii) In any region, various additional circumstances determine the extent of the hazards arising from *Salmonella*-polluted meat. The temperatures at which meat is customarily stored, the frequency and intimacy with which it is liable to be handled, the types of meat and sizes of joints favoured, and the mode of curing or cooking, will all influence the amount of initial pollution, and the rate of proliferation of any implanted pathogens. However, although very different settings and circumstances govern the conveyance of salmonellosis—for example, by raw seal meat in an Eskimo igloo, or by lamb stew in an Arabian village—the crucial features common to both situations are human faecal pollution and improper temperature control of the meat.

Table II illustrates the value of stool cultures in establishing epidemiological connexions between the staffs and infected patrons of public eating-places. Towards the end of the Second World War, three outbreaks of salmonellosis occurred in a western Canadian city. The rather low hygiene standards of food service then prevailing had been reflected in numerous sporadic outbreaks of salmonellosis, most of them with no obvious clues as to sources ; but in the first two episodes, a high proportion of the guests at a cold turkey luncheon and a smörgåsbord dinner, respectively, became ill with acute gastro-enteritis between 12 and 36 hours later. City health department officials procured faeces specimens for laboratory examination from the food-handling staffs and the affected patrons, with the results shown. Interrogation of staff members yielding positive cultures showed them either to have been symptomless carriers or to have had mild gastro-intestinal upsets at the time of the outbreaks.

The third episode gradually came to light after a club dinner which caused a febrile gastro-intestinal illness in at least 38 persons. When the outbreak was investigated, nearly one month later, it was too late to identify the vehicle, though cold ham was suspected ; but some possible human sources of the outbreak were still detectable.

The epidemiology of this type of food poisoning outbreak is seldom as clear-cut as in the foregoing instances. In the Netherlands, for example, over the period 1949-52, an intravital infection of the meat was established in 4 out of 19 outbreaks of meat-borne salmonellosis investigated, while

TABLE II. LABORATORY FINDINGS IN THREE OUTBREAKS OF SALMONELLOSIS TRACED TO RESTAURANTS IN A WESTERN CANADIAN CITY (MARCH-AUGUST, 1946)

Place	Number of patrons submitting specimens	Number of individuals positive for salmonellae	Number of staff submitting specimens	Number of individuals positive for salmonellae
Café ES	5	5 *S. typhimurium*	29	8 *S. typhimurium*
Grill H	7	6 *S. thompson*	18	5 *S. thompson*
Café ED	38	7 *S. typhimurium* 2 *S. paratyphi* B	21	3 *S. typhimurium* 1 *S. paratyphi* B

in the remainder the source of contamination was undetermined.[27] Indeed, very extensive meat-borne epidemics sometimes occur, in which the etiological agent is readily enough elucidated, but the epidemiological evidence is equivocal or inadequate. In Berlin, in 1950, about 1000 persons became ill, most of them rather slightly, after eating boiled ham.[125] *S. london* was isolated from the faeces of about half the total cases, as well as from the ham, and from 10 of the butcher's staff on whose premises the ham had been kept. The initial source of the ham infection may have been zoonotic, but was not actually traced, and pollution by a carrier among those who handled it in bulk is at least a possibility.

Similar hiatuses appear in recent reports of meat-borne salmonellosis outbreaks from England and Wales. For instance, in one week of June 1953, in Lancashire, about 1150 persons became infected with *S. bovis morbificans*, conveyed by meat pies. The large bakery which manufactured the pies was modern, maintained good hygienic practices, and showed no evidence of rodent infestation. Since this particular *Salmonella* had comparatively seldom been incriminated in human infections in that locality, was not isolated from any suspected carrier engaged in manufacture of the pies, and is characteristically a bovine pathogen, attention was focused upon the sources of the meat used during the relevant period. Altogether, portions of the carcasses of 11 animals had been received by the bakery. Some suspicious feature attached to four of the five carcasses whose antecedent history was traceable, but they could not definitely be implicated bacteriologically. Although the circumstantial evidence favoured intravitally infected meat as the more probable cause of this serious outbreak, manufacturing practices were disclosed which entailed risks of human carrier-borne infection, such as the system of pouring warm gelatine solution by hand into each cooked pie through a small

hole in its lid. *S. bovis morbificans* was experimentally inoculated into 60-g and 120-g pies, and survived baking for 50 minutes at 320°F (160°C) in sufficient numbers to ensure a grossly infected article upon subsequent addition of gelatine. Exposure to 380°F (193°C) or to a longer cooking time (60 minutes) proved lethal for this organism. The records of the bakery oven over the critical period showed that the temperatures and cooking times were insufficient to kill all salmonellae of this type present in the pies, so that surviving pathogens could multiply rapidly in the prevailing hot weather.[89]

Comparable difficulties prevented final unravelling of the primary source of infection in another meat-pie poisoning outbreak which occurred in England in December 1951. Some 500 cases of acute gastro-intestinal illness were reported in two midland counties, and were almost all traceable to one batch of pork pies. The organism concerned here was *S. minnesota*, then novel to the British Isles, and suspicion was therefore directed upon imported frozen pork, which had been used recently for the first time by the pie makers. However, although one sample of the pork (taken from the factory) yielded *S. minnesota*, this organism was also isolated from a swab of the meat-cutting bench where the case of pork had been opened. Other attempts to pin down the actual source of infection were equally inconclusive. The likeliest vector was finally presumed to be either an adjoining slaughterhouse worker, normally engaged in gut-washing, or a bakery employee whose customary duties were weighing raw meat used in the preparation of pies. At the material time, both these individuals were involved also in pouring gelatine solution into the cooked pies.[88]

Again, in the autumn of 1951, an outbreak of gastro-intestinal infection occurred at a girls' school in Yorkshire ; it especially illustrates the importance of adequate cooking of meat dishes when the ingredients are likely to have been contaminated by human handlers some hours beforehand. Among 439 girls served a mid-day meal of which the first course was shepherd's pie, 63 clinical cases of paratyphoid fever developed, while 47 apparently healthy children were found to be excretors of *S. parathyphi* B. The pie was prepared by stewing fresh minced meat in water, straining it from the stock when cool, and placing both meat and stock in the refrigerator overnight. Next morning, the meat was distributed into large enamel dishes, each holding 50 helpings, some stock was added, along with freshly-cooked onions and potatoes, and the completed pies were baked in the oven for periods ranging from 25 to 60 minutes.

The space and equipment in both kitchen and dining-room were very limited, and the meal had to be served in three sittings. The attack rate proved highest in the youngest girls who arrived first to dinner and whose portions had least time in the oven ; while no cases occurred in the oldest girls who came in last, and were served direct from dishes which had gone

on cooking in the kitchen. Faecal cultures of the kitchen staff were not done until 24 days after the presumed infection of the pies, by when only one worker was excreting *S. paratyphi* B. She was solely employed in drying plates by hand, and was considered a victim, rather than the cause, of the outbreak. Of the remaining six employees, serological examination suggested that three, including the cook, had recently been infected with *S. paratyphi* B. As most of the kitchen staff ate their meal before the first sitting, while the cook always ate after the third sitting, the latter was considered the probable instigator of the outbreak.

Temperature measurements of experimental pies removed from the oven after appropriate intervals showed different parts of the same pie to vary by as much as 5°C. The lowest temperature recorded in the cooked pies was 65°C, which should have been lethal for *S. paratyphi* B, but pies removed later were from 5° to 7°C warmer, and it may be inferred that in pies cooked for a few minutes less than usual the thermal death-point of paratyphoid bacilli would not have been reached.

Useful lessons can be learned also from an outbreak of typhoid fever, affecting 42 persons, which occurred in April, 1949, at the village of Crowthorne, Berkshire.[151] Three butchers supplied the inhabitants of about 1000 households with meat, but all the victims had eaten corned beef obtained from one butcher. This corned beef came from a number of tins, and had been cut into thin slices for privileged customers on three known days. Scattered cases of typhoid-like illness began to develop between five and seven days later, from all of which the same type of *S. typhi* was isolated. Blood, faeces, and urine specimens from the butcher's family and working associates proved negative for *S. typhi*. A known typhoid carrier in a neighbouring village was exculpated when Vi-phage typing showed his organism differed from the Crowthorne strain. Although epidemiologically the vehicle in this outbreak was definitely corned beef, which must have been contaminated from a human source, the actual origin was not discovered. The wiping-cloths customarily used in the butcher's establishment were coverings from imported mutton carcasses, and one of these may have been polluted in transit with *S. typhi*, which could have survived cold storage, to be transferred eventually to the corned beef as it was sliced on the wiped-down counter.

Control

The first three of the foregoing epidemics illustrate mainly the nature and extent of the consequences which may result from neglect of proper temperature control in the preparation and storage of meat. Regardless of the sources of the salmonellae, each of these episodes might have been averted had the implicated meats been exposed to the same oven temperature

for a slightly longer period or to a somewhat higher temperature for the same time. However, the sterilization of pies by adequate cooking may be nullified by such customs as the subsequent addition of gelatine solution by hand. The pouring of contaminated gelatine into thoroughly cooked pies [78] or even (were it feasible) the aseptic insertion of sterile gelatine into insufficiently cooked pies containing viable organisms, must result in a potentially dangerous comestible. Further, exposure of such foods for some hours to warm summer temperatures of course promotes bacterial proliferation; and hence certain types of bacterial food poisoning are more prevalent at this season. Nevertheless, the occurrence of the four episodes cited above at different seasons of the year emphasizes that growth of salmonellae in a meat medium is governed primarily by the temperature range to which that medium is exposed, regardless of the weather. In fact, the prophylaxis of these forms of food-borne infection through temperature control is biphasic. One phase is concerned with the application of sufficient heat to the foodstuff to achieve destruction of all pathogens present: the other with maintenance of a temperature low enough to reduce to a minimum the multiplication of chance survivors or of later implanted pathogens.

This twofold objective cannot be quickly accomplished, for culinary beliefs and practices established for generations are not lightly gainsaid or reformed. Careful and persistent programmes of public health education must be conducted by teachers thoroughly familiar with the less well-recognized facts of temperature control. For instance, attention was drawn earlier to the comparatively low temperature reached at the centre of a large ham or joint of meat during roasting, frying, or boiling processes. The same observation holds for meat pies, shepherd's pie, and similar baked dishes. Again, though refrigeration of meats and meat products is undeniably important, the effectiveness of this measure is apt to be over-estimated. Such foods, placed in the refrigerator while still warm after being cooked, or exposed in a hot kitchen, may take some hours to cool down to a temperature at which bacterial multiplication or toxin production is negligible.[93] Indeed, sometimes these activities continue slowly at between 6°C and 10°C (the customary temperature range of electric household refrigerators), and in any event such low temperatures help to preserve the viability of salmonellae, and the potency of preformed staphylococcus enterotoxin or botulinus toxin. To sum up, the adequate cooking and efficient cooling of all meat foods are preventive measures of paramount importance; but uninformed reliance upon baking and refrigeration as sole safeguards may end in serious disillusionment.

Other control measures are obviously necessary, which must centre around the complex task of reducing the chances of transfer of human faeces to meats. This is again primarily a problem of public health

education, although to be effective—as generally holds throughout life—the educational techniques must be buttressed by sanctions. Nearly every food handler, despite the simple habits of personal hygiene learned in earliest childhood, and explained in lessons at school, tends now and again to be forgetful or careless, and thus to endanger the health and even lives of others. Health departments therefore have a manifold obligation to fulfil. First, they can give leadership and guidance in planning authoritative curricula for health teaching in schools and colleges, and can assume responsibility for instructing restaurant owners and key employees in sanitary principles and practices. Secondly, they can initiate and firmly implement suitable by-laws and regulations bearing on restaurant sanitation; and where the letter of the law is not specific, can faithfully interpret its spirit. Thirdly, they can regularly inspect all public eating-places, with a view to securing scrupulous cleanliness of kitchen and food storage space; adequate toilet accommodation (with clean towels and soap) for patrons and staff; and proper cleansing of utensils and crockery. Where laboratory facilities exist, apparent cleanliness may be checked against bacterial counts on swab samples from such sites as chopping boards, mincing machines, and cutlery. In this connexion, a simple device of considerable educational value is the Jamieson Kit,[111] which reveals the amount of contamination present on various swabbed areas of restaurant equipment, in terms of bacterial and fungal colonies developing on slopes of nutrient medium in vials held at room temperature. Fourthly, health departments can conduct periodic health examinations of food handlers. These may advantageously include bacteriological tests of faeces samples, any *Salmonella* carriers thus revealed being banned from direct food handling until several successive cultures have been reported negative. If the public health laboratory cannot shoulder such extensive undertakings, then hospital authorities must at least inform the local Medical Officer of Health about all patients discharged during convalescence from gastro-intestinal infections; and he should be prepared to take any action deemed necessary against food handlers who may be actual or potential excretors of these pathogens.

In some communities, restaurants are graded according to the hygienic standards they maintain, the best being awarded a seal or badge of merit, while unsatisfactory ones are granted few warnings before withdrawal of their licence. Other authorities prefer to function in an advisory rather than a judicial capacity, leaving the assessment of sanitary and other qualities of restaurants to be settled as far as possible through competition and customer discretion. Regardless of the system prevailing, there is bound to be a wide range in the menus and amenities offered by the eating establishments in any region, but an alert health department should not rest content unless the humblest patron in the cheapest café can eat a meal

there with as little risk of salmonellosis as the clientele of the most exclusive restaurant. The practical aspects of the hygiene of food preparation and service are so conditioned by local custom and prejudice that some latitude is inevitable; but they must take cognizance of, and should nowhere be allowed to contravene or lag far behind the known principles and generally accepted standards of sanitary bacteriology.[28]

Human faecal pollution of meats is not always finger-borne, but may be conveyed also by insects or by inanimate objects. Among insects, the common housefly (*Musca domestica*), because of its breeding and feeding habits and world-wide prevalence, is potentially a very important mechanical vector of faecal pathogens.[164] Cockroaches are another possible menace, owing to their liking for warm places where food is kept, their catholicity in choice of foodstuffs, and their ability to excrete salmonellae in the faeces for 10-20 days after experimental feedings.[162] Fly-proofing, judicious use of insecticides, and the stoppage of harbourages, are the basic control measures needed here. A second line of defence is to protect meats by cellophane wrapping, or by exhibiting them only on refrigerated counters under glass. The stacking of meats for sale in unsheltered shop windows, or on open carts, should not be tolerated.

The Crowthorne typhoid epidemic, mentioned above, illustrates the necessity for scrupulous cleansing of meat counters, particularly when cooked meats, such as corned beef, sausages, and ham, are being sliced or dispensed. The top surfaces of all such counters and tables should be constructed of impervious material. Hand towels and wiping-cloths should be sterilized, kept separate, and frequently changed. Meat-chopping blocks should be scraped free from debris and thoroughly scrubbed. Mincing machines and other apparatus should be taken apart, regularly cleaned, and sterilized whenever possible. Useful data and detailed recommendations about the hygiene of catering establishments may be found in a report published in Great Britain in 1951 by the Ministry of Food.[84]

Whether the mode of pollution of meat is by fingers, flies, or fomites, pathogens of human faecal origin are much more likely to gain access to extensively handled meat products. Such foods are particularly popular in the United Kingdom, where their liability to become vehicles for bacterial food poisoning has caused concern for some years. In 1950 the Ministry of Food issued a valuable report, featuring desirable improvements and safeguards in the manufacture of processed and made-up meat products.[85] In a section headed "Education", the committee expressed as follows the gist of the problem:

"Personal standards of cleanliness vary according to the individual's background, training and understanding of the value of hygienic practices. If a high standard of

hygiene in the meat products trade is to be secured, personal standards of cleanliness must be raised and in this education will play an important part ... Education should lead to understanding and understanding to action. The responsible manufacturer who fully understands the risks of food poisoning will take such action as he can to reduce them, and will not only comply with legal requirements but will observe the provisions of a code of practice. Similarly, the responsible worker realising how ingredients and products can become contaminated as a result of failing to wash the hands thoroughly after visiting the lavatory, and the serious consequences that may follow, will certainly wash his hands. It is not a question of spreading alarm among the staff, but of creating an attitude of mind which will result in the habit of cleanliness."

Shigellosis

The shigellae are primarily human intestinal pathogens, so that when a member of this genus has been identified as the cause of an epidemic, it may be presumed generally that the source was the faeces of a human case or carrier of bacillary dysentery. These organisms have been classified, biochemically and serologically, into several species, of which *Sh. shigae, flexneri, boydii,* and *sonnei* are the best known. The first-named is the most dangerous, but its distribution is sporadic, whereas the less serious *flexneri* and *boydii* species, and the relatively benign *sonnei* species, are widespread throughout the world. Although several other species have been differentiated, since the shigellae lack flagellar antigens they cannot be expected to attain the taxonomic complexity of the salmonellae. Most species and types of *Shigella* may be involved, at least theoretically, in meat-borne infections.

Some authorities have doubted the existence of "healthy" carriers of dysentery bacilli. However, this is a purely academic question, difficult to settle because of the frequently mild nature of the symptoms, especially in Sonne dysentery. Certainly "convalescent" and "chronic" carriers and asymptomatic cases are not rare, and when identified should be debarred from food handling. In one recorded instance, an excellent chef at an army officers' mess was found through a routine survey to be an intermittent excretor of *Sh. sonnei*. He was reluctantly discharged, only to be discovered ten months later by public health officials working as a chef at a local hotel and still excreting *Sh. sonnei*.[45]

Flies often play an important part in epidemics of shigellosis, particularly in camps where poorly constructed latrines encourage their breeding. In 1942, an outbreak of 1557 cases of Flexner dysentery took place in a large army camp bivouacked in the southern USA. The onset occurred about two weeks after troops had moved into an area in which flies had begun to breed extensively because of improperly operated straddle trench latrines. *Sh. flexneri* type 6 was cultured from rectal swabs taken from

many of the affected men, and from 9 lots of flies collected in the kitchens and latrines. Among 443 food handlers the rate of asymptomatic cases or carriers was 10.8%. Although no particular foods were implicated, circumstantially there is every likelihood that meat was among the vehicles of infection.[126]

The extent to which flies and probably also human carriers can pollute fresh meats with shigellae, and thus contribute to the known high incidence of meat-borne gastroenteritis in the Middle East, was demonstrated by a recent cultural survey of meat samples purchased from 53 butchers' shops in Cairo, Egypt. Enteric pathogens were isolated from 21, or 8.4%, of 250 meat samples examined. Two samples each yielded two pathogens, making a total of 23 isolations. The majority of these (14, or 61%) were shigellae, and the remainder were salmonellae, the types being those commonly encountered among human cases of gastro-enteritis in Egypt. If this survey, which was conducted in winter, had been repeated during the summer months, a still higher contamination rate could have been anticipated.[65]

The epidemiology and control of meat-borne shigelloses are to all intents identical with those outlined for certain forms of salmonelloses (see pages 60-69).

The Role of Proteus, Coliform, and Paracolon Bacilli in Meat-borne Infections

The enteric bacilli (Enterobacteriaceae) include certain groups of intestinal commensals, such as *E. coli*, paracolon bacilli, and *Proteus*, which are generally non-pathogenic to man. These organisms are so prevalent in the human intestine that their presence in foodstuffs should be regarded as presumptive indices of human faecal pollution rather than as a direct menace to health. Fresh meats subject to much handling, for example, minced or ground beef, and ready-to-eat products, such as sausages, brawn, or meat-loaf, are particularly prone to contamination with these enteric bacilli. For instance, of 250 samples of ready-to-eat meats collected from butcher shops and provision stores in Cairo in 1952, every specimen showed the presence of *E. coli*, while 39% contained paracolon bacilli, and nearly 24% were contaminated with *Proteus* species.[66] If these organisms were frequently pathogenic, consumption of ready-to-eat meats would be a hazardous indulgence indeed. Nevertheless, sometimes a foodstuff may be implicated epidemiologically which displays such heavy contamination with one of these organisms in almost pure culture that a causal relationship is naturally postulated. In Germany, 11% of roughly 2500 cases of food poisoning were ascribed recently to these and other aerobic bacilli.[209]

Relatively short incubation periods have characterized most food poisoning episodes supposedly due to *Proteus* and related enteric commensals, suggesting that preformed toxic metabolites were present in the implicated vehicles. For instance, in one outbreak, 19 USA naval personnel were hospitalized with acute gastro-enteritis about three hours after ingesting baked ham slices. The presence of large numbers of *Proteus mirabilis* was demonstrated in the ham, and in the faeces of 9 of the patients.[25] In another outbreak of severe vomiting and diarrhoea, which led to the hospitalization of 9 persons at Bristol, England, the onset of symptoms occurred within three to five hours after the meal in all cases except one, whose vomiting began after 36 hours.[33] From the suspect brawn, and from the patients' faeces, a strain of *Proteus vulgaris* was isolated. A similar organism was present in a brine pickle wherein the meat used to make the brawn had been kept for 3 days. (Brine baths are evidently potential sources of meat-borne infection, for the same brine may be used to pickle many successive batches of meat.) Filtrates prepared from the suspect culture provoked vomiting and diarrhoea when injected intraperitoneally into young kittens. This was held to signify the production of an enterotoxin. However, although Jordan & Burrows [114] reported that enterotoxic reactions could be provoked in monkeys by feeding them culture filtrates of various bacteria, including *Proteus* and *E. coli*, these workers stated that they had repeatedly fed *Proteus* filtrates to human volunteers without ill effects. Again, Dolman [45] induced enterotoxic reactions in kittens by injection of filtrates of *Proteus* and *E. coli* cultures isolated from implicated foods; but human volunteers swallowed with impunity relatively large amounts of the same filtrates. Monkey and cat reactions therefore seem to be unreliable guides to the food poisoning propensities of such enteric bacilli for man.

In other experiments, volunteers suffered no ill effects from eating meat pies artificially infected with a strain of *P. vulgaris* (derived from pressed beef involved in a food poisoning outbreak), or with a strain of *E. coli* isolated from similarly suspect meat and vegetable pie. To test the hypothesis that staphylococcus enterotoxin might persist in a foodstuff after the culture originally responsible for its production had been overgrown by secondary contaminants, variously inoculated wiener sausages were given to volunteers. Portions of one sausage badly decomposed by growth of *P. vulgaris* were consumed without harm, whereas portions of another sausage (of normal appearance) in which enterotoxigenic staphylococci had grown, caused severe vomiting and diarrhoea in the same persons within three hours. A third sausage was inoculated, first with this staphylococcus strain, and then 4 days later with the *Proteus* culture. After a further 3 days at room temperature, by when bacterial counts showed the staphylococci to have been almost completely superseded by *Proteus*,

comparable amounts of this sausage again caused severe reactions in the same consumers.[45] These experiments confirm the possibility that a food poisoning episode actually due to staphylococcus enterotoxin might be ascribed erroneously to *Proteus*; but they do not exclude the latter genus altogether from primary or contributory relationships to food poisoning.

Similar uncertainties becloud the food poisoning role of coliform and paracolon bacilli. There are no convincing reports which directly implicate *E. coli* in outbreaks of food poisoning. However, since Bray[15] first reported in 1945 the isolation of a particular type of coliform organism from the faeces of infants with gastro-enteritis, increasing acceptance has been accorded to the claim that certain serotypes of *E. coli* can cause outbreaks of infantile (and adult) gastro-enteritis. Moreover, volunteers developed diarrhoea after drinking milk containing large numbers of coliforms of specific serotypes,[63, 116] while similar types have been isolated from water and from flies.[204] Such findings certainly suggest that appropriate strains of *E. coli* could give rise to cases and outbreaks of meat-borne gastro-enteritis.

The paracolon group of organisms has been reported rather more frequently than *E. coli* as a cause of food poisoning. Although the vehicle has typically not been meat, a notable exception was an outbreak attributed to turkey fricassée, which affected 93 delegates to a food technologists' convention, at Glenwood Springs, Colorado, in September 1951. Remnants of the turkey yielded around 10^{10} organisms per gram, the majority being paracolon bacilli. While still hot, the cooked bird had been immersed in cold water of doubtful purity. From this water supply, similar types of organisms were subsequently isolated.[196] In a recent summary of the somewhat conflicting evidence relating to this group, Taylor[204] suggests that strains of paracolon bacilli differ widely in pathogenicity, the majority being harmless. Accounts of alleged outbreaks from various parts of the world agree in setting the incubation period at 8-24 hours. In this respect, and also in symptomatology, outbreaks of food-borne gastro-enteritis ascribed to paracolon bacilli resemble many of the *Salmonella* infections.

Control

All meat-borne infections caused by pollution with human intestinal bacteria exhibit basically the same epidemiological pattern, and are governed by the same principles of control. Hence the preventive measures applicable to the *Salmonella-Shigella* genera need not be recapitulated. However, one measure advocated in the preceding section (see pages 60-69) calls for comment. The search for carriers of acknowledged pathogens among food handlers is obviously pointless unless pathogenic and harmless strains of *Escherichia* and *Proteus* can be differentiated. Many of these organisms

may be borderline or facultative pathogens, whose activities depend on certain host factors, and even perhaps on the coincident presence in the intestinal flora of other bacteria or viruses.

Certain *E. coli* cultures isolated from hospital outbreaks of infantile gastro-enteritis seem distinguishable serologically. Further investigation may reveal that type 1 strains of *E. coli* may also be occasional agents of food-borne gastro-enteritis affecting older age-groups. Similarly, among the paracolon bacilli, the so-called Arizona, Ballerup-Bethesda, and Providence groups have been serologically differentiated, and are apt to display pathogenic qualities. On the other hand, the classification of *Proteus* remains quite unsettled. There are evidently many gaps and uncertainties; and more collaborative work is needed between bacteriologist and epidemiologist, aided by the sanitary inspector, before a carrier can be justifiably banned from food handling, or a foodstuff definitely incriminated, on the sole strength of such cultural and serological findings.

The presence of these organisms on foodstuffs is regarded by some public health officials as a presumptive index of pollution. The environment of meats nevertheless includes air, soil, insects, and the tissues and excreta of higher animals, apart from human faeces. Such ubiquitous organisms are therefore apt to be misleading as qualitative indicators; [37] and their usefulness, even as quantitative guides to sanitary standards in the handling of meat and other foodstuffs, is controversial.[205]

Astonishingly heavy degrees of contamination may be demonstrated in meat and fish, and their respective products, without illness resulting from their consumption. However, Hobbs [103] has shown a definite relationship between high bacterial counts in such foodstuffs and their involvement in food poisoning. For meats, her findings indicate that total counts higher than 10^7 organisms per gram should be deemed hazardous. Incidentally, over 20 years ago at least one large city in the USA made illegal the sale of any unseasoned ground meat (hamburger) with an average bacterial count exceeding 10^7 organisms per gram.

The proper limitations to be set upon the functions of the bacteriologist in food sanitation control have been succinctly expressed as follows by Wilson:

> "It is far more important to lay down a strict code for the preparation and processing of food and see that it is carried out properly than to rely on bacteriological sampling of the finished product. Bacteriologists have a considerable part to play, but if they are wise they will spend their energies in devising means of preventing or overcoming contamination rather than in pandering to the demand of sanitary authorities for more and more sampling. Samples are essential, and a simple reliable technique for examining samples is essential, but sampling can be no more than a check on the efficacy of the processing; and it is the high quality of the processing maintained day after day that is required to ensure the safety of many of our foods." [219]

Food-borne Viral Infections

Experimental and epidemiological data indicate that two important viral infections, poliomyelitis and infectious hepatitis, are mainly conveyed by human faeces; from which it follows that they could be transmitted by excreta-polluted foodstuffs, as well as milk and drinking-water.

In outbreaks of poliomyelitis the evidence incriminating these vehicles, and also flies as vectors, has been rather inconclusive. There are two factors in favour of the hypothesis that flies are often implicated: (*a*) the correspondence of the season of highest prevalence of the disease with the time when flies abound and when undoubted fly-borne enteric infections are liable to occur; and (*b*) the recovery of poliomyelitis virus from various species of flies.[140] Against this hypothesis are the unlikelihood that flies could frequently convey infective dosages of virus from human faeces to food (since no proliferation of the virus can occur in food), and the apparent failure of fly suppression programmes to affect poliomyelitis epidemics. However, the acquisition of non-paralytic poliomyelitis, and the persistent excretion of the virus, by apes fed shortly beforehand upon material exposed to flies in an epidemic area, are very significant observations.[215] If flies are able to contaminate bananas sufficiently with human faeces to infect chimpanzees, food-handling excretors of the virus might convey human-infective doses to foodstuffs such as made-up meats.

Experiments with human volunteers leave little doubt that the infectious hepatitis virus is excreted in human faeces and is transmissible to man by the oral route.[157] Moreover, in certain outbreaks a definite foodstuff appears to have been implicated. The fact that meat has not featured as the designated vehicle in such outbreaks does not exclude it from consideration. Of course, the nature and consistency of most meats renders them less prone than, for example, custard [7] to fairly even distribution of faecal pollution throughout their substance. Nevertheless, in view of the widespread prevalence and high infectivity of this disease, and of the persistent excretion of the virus in the faeces during convalescence from mild or non-icteric attacks, many individuals must be exposed sporadically to ingested virus on the surface of meats. Contamination of such meats could occur either before they are purchased ready-to-eat, or after they have been home-cooked and subsequently consumed in a cold or warmed-up state.

Other viral agents, such as the Coxsackie group, appear to be mainly excreta-borne, and have been isolated from human faeces and flies; while certain viruses may occasionally use the intestinal tract as an alternative to their more customary portals of entry. More relevant is the possibility that viruses as yet unidentified may account for at least a proportion of those epidemics of gastro-enteritis for which no bacterial cause seems

adducible. One such virus was demonstrated nearly 10 years ago by Gordon et al.,[79] who transmitted gastro-enteritis to volunteers through oral administration of human faecal filtrates. Dearth of susceptible laboratory animals, and difficulties inherent in resorting to human subjects, hamper investigations of this kind, but it seems justifiable to anticipate by analogy, and on *a priori* grounds, that a plurality of such viruses, acting either independently or in concert with intestinal bacteria, will be found capable of inciting certain forms of gastro-enteritis, and therefore likely to be at least theoretically involved in meat-borne infections.

Staphylococcal Food Intoxication

Mode of infection

The commonest of all forms of food poisoning is probably the acute gastro-intestinal disturbance which occurs in susceptible individuals typically within two to five hours after ingestion of foodstuffs containing a toxic metabolite produced by certain strains of *Staphylococcus*. Yet only within the last two decades has this condition become widely recognized. Indeed, for some years after the prevalence of staphylococcal food intoxication had been acknowledged in North America, bacteriologists and public health authorities in the United Kingdom and many other countries remained unconvinced of its existence. Their scepticism apparently arose because organisms so ubiquitous were considered inevitable contaminants of foodstuffs. Hence, it was argued, either most strains of *Staphylococcus* are liable to cause food poisoning, so that practically everyone is inescapably exposed to recurrent risks; or relatively few strains are so endowed, thus making it difficult to incriminate staphylococci epidemiologically and medico-legally in any given outbreak—unless a simple laboratory test for this property were forthcoming. The dilemma has now been superseded by the generally accepted view that certain strains of *Staphylococcus*, regardless of their sources, are able to elaborate a filtrable substance, the so-called enterotoxin, in many types of foodstuffs, including meats and meat products, without altering their appearance, odour, or taste. This agent does not act directly upon the enteron, but is absorbed from the gastro-intestinal tract, and provokes vomiting and diarrhoea by a specific effect upon the central nervous system. Roughly 20%-35% of adults seem to be relatively insusceptible to the enterotoxin. Although affected persons as a rule recover quickly and fully, occasional fatalities are on record.

The pharmacology, chemical nature, and antigenic properties of the enterotoxin remain elusive; while the most reliable method of detecting it is still a matter for dispute. Among the common laboratory animals,

only the monkey and the cat seem suitable for this purpose. When due precautions are taken against non-specific reactions [45, 51] the cat gives more satisfactory results than the monkey.[139] Both animals are less susceptible than man to enterotoxin, but human volunteers should be resorted to only for crucial experiments. Although there is a tendency for food poisoning strains to fall into certain bacteriophage-susceptible types, no *in vitro* method yet devised affords conclusive evidence of enterotoxigenicity.

In 1914, the classic report of Barber [9] demonstrated that outbreaks of gastro-intestinal distress affecting visitors to a farm in the Philippine Islands were caused by the milk of an apparently healthy cow which contained *Staphylococcus albus*. In a high percentage of more recent reports, milk and milk products, consumed either as such or in the form of ingredients, have been implicated. These foods are common vehicles for several reasons. Their fluid or semi-fluid nature, and their chemical composition, render them particularly suitable as nutrient media; they are very prone to staphylococcal contamination from the air and from handlers, as well as from the bovine udder; moreover, in many parts of the world confections and pastries are still exposed in shop windows to the gaze of the customer and the sun's rays. Meats, however, also provide excellent media for staphylococcal proliferation. Indeed, in appropriate circumstances, meat gravies [52] and soups may become highly toxic, as witness the recorded death of a woman, aged 61, apparently from staphylococcal food intoxication. One week previously, while suffering from a whitlow of her thumb, she had opened a tin of soup, and partaken of the contents. There were no ill effects, and the thumb healed. Six days later, she decided to finish the soup, which had been kept meanwhile in her warm kitchen. Within 3 hours of eating the warmed-up soup, she fell ill with violent vomiting and diarrhoea, and was admitted to hospital moribund 22 hours later, where she died shortly afterwards. Large numbers of coagulase-positive, haemolytic *Staphylococcus aureus* were isolated from the alimentary contents and from inside the empty soup tin.

The rather dense consistency of meat may hinder diffusion of enterotoxin produced on or near its surface; but eventually quite deep penetration may occur, especially in cured meats such as ham or tongue, which can be kept at room temperature for many days, and are subject to much handling. For instance, about 15 years ago in eastern Canada, a man died with typical symptoms of severe staphylococcal food intoxication some 24 hours after eating the remains of a ham which had been kept for 4 days in a drawer at a rooming-house.

Actually, if the prevailing temperature be warm enough, only a few hours are needed for the production of effective amounts of enterotoxin.

In a large outbreak of this type, involving around 200 men working on an Indianapolis relief project, the causal food was tongue sandwiches.[38] The sandwiches had been made less than 12 hours previously, but were exposed to outdoor temperatures up to 90°F (32°C) during the day. Afterwards, bread was shown experimentally to be a favourable medium into which enterotoxigenic staphylococci might penetrate from contaminated tongue used as a sandwich filler.[118] In another outbreak, affecting a group of Canadian soldiers on manoeuvres, the vehicle was sliced ham. After having been boiled on the previous evening, the ham was kept overnight in the cooler at 45°F (7.3°C), and next morning was packed by hand into an airtight thermos container, which had been scalded just beforehand and was doubtless still warm. About 10 hours later, the ham was served to 66 persons, of whom 53 were shortly taken ill, some appearing so prostrated that it was feared they might not reach hospital alive.[45]

Smaller and milder outbreaks than these, as well as familial and individual instances of staphylococcal food intoxication, are commonly ascribed to allergic and other forms of digestive upset, or are overlooked when the attack proves evanescent. In earlier days, metallic and other poisons were often invoked to account for such mishaps. Perhaps the earliest account of staphylococcal food intoxication was reported from France in 1830, when Pasteur was only 8 years old. Three hours after dining on ham pie, purchased from a pastry-cook in Paris,

" the master of the house was seized with general uneasiness, followed by cold sweats, shivering, violent pain in the stomach, and frequent vomiting; then with burning thirst, extreme tenderness of the belly, so that the weight of the bed-clothes could scarcely be borne, profuse purging, and colic of extreme violence. His daughter, 27 years of age, and a child 9 years old, were similarly attacked ... In a few days all the three individuals recovered under an antiphlogistic treatment. About the same period several accidents of the like nature occurred among the customers of this pastry-cook; and in consequence a judicial investigation was ordered. The shop being properly inspected it was found that every operation was conducted with due attention to cleanliness ... The pye did not contain a trace of arsenic, copper, antimony or lead."

The Lancet commented thus on the episode:

" Had the accident occurred before Orfila reduced toxicology to a science, it is more than probable that the unfortunate pastry-cook would have been condemned as a felon and sent to the guillotine." [127]

An equally graphic account of a severe outbreak antedates by 20 years Ogston's identification of the *Staphylococcus*, and by half a century Barber's association of this organism with food poisoning.[18] A family of 10 persons, having at dinner partaken of a rabbit-pie, were all shortly afterwards seized with diarrhoea and violent pains in the abdomen, which continued throughout the greater part of the night. Considerable relief

was obtained by the administration of some astringent medicine. On the following morning, however, the precise cause of their illness not being suspected, several members of the family again partook of the remnant of the pie, reproducing the symptoms of the previous day in an alarmingly aggravated form, with the addition of vomiting and violent cramps of the lower extremities. The physician summoned found

" one of the patients in a state of collapse, pulseless and insensible, and bathed in a cold, clammy perspiration. The others were also suffering more or less severely in proportion to the quantity of the poisonous food each person had eaten."

They soon began to recover under stimulants and opiate treatment. The rabbits and other materials composing the pie were perfectly fresh —but after baking, the pie had stood for two or three days in very hot weather.

Nowadays, when notified of such episodes, an alert health department arranges for the cooks and other food handlers to be examined for staphylococcal infection, particularly of the hands and arms, and takes nose and throat swabs for evidence of a carrier state. By phage-typing methods, important links may be established frequently between the strain of *Staphylococcus* found to predominate in the suspected foodstuff, and other strains isolated from persons preparing or handling that food.[184] In a recent Ministry of Health report, four such meat-borne outbreaks occurring in various parts of England were briefly described. Two of these, caused by tongue, involved 30 and 5 persons respectively, one, caused by brawn, involved 19, and one, caused by ready-cooked rabbit, involved 11 persons. In each instance, the staphylococci isolated from the incriminated food and from one or more persons intimately associated with its preparation were of identical phage types. For example, *Staphylococcus aureus* type 7 was isolated from a cold boiled tongue and from patients' specimens, as well as from the nose, throat, and a cut on the hand of the person who prepared the tongue.

Control

Since the characteristic syndrome illustrated above is wholly explicable in terms of the ingestion of pre-formed enterotoxin in food, the overriding principle in the control of meat-borne staphylococcal poisoning must be to avert enterotoxin formation. In attaining this objective, the main factors to be reckoned with are the ubiquity of the genus concerned; the complexity of the available methods for identifying enterotoxigenic strains; the relatively low temperatures at which enterotoxin may be produced in suitable foodstuffs; and the unusually high thermal resistance of this substance. The problem is vulnerable to a three-way approach, comprising: (i) minimization of access of enterotoxigenic staphylococci

to meats, especially manufactured and ready-to-eat products ; (2) destruction or inhibition of staphylococcal contaminants by heat, chemicals or antibiotics ; and (3) inhibition of enterotoxin production by adequate refrigeration. A fourth theoretical possibility, namely, active immunization against the enterotoxin, has been demonstrated on a small group,[46] but seems unlikely to have large-scale applicability.

(1) The difficulties previously outlined in connexion with preventing pollution of meats by human intestinal organisms become multiplied when the control measures must be extended to cover organisms present in air-borne dust and droplets, on almost any area of human skin and mucous membranes, and also on clothing and utensils. The logical *reductio ad absurdum* of the situation has been summarized as follows :

> " Speculation as to the possibility of altogether eliminating such contamination soon exhausts itself in devising obviously impractical measures. For not only would food handlers have to be always well scrubbed, and their hands free from pimples and abrasions, but they should also be certified not to carry enterotoxigenic staphylococci in their nose and throat. Moreover, they should always wear freshly-laundered caps and gowns, their utensils should be thoroughly scalded before and after use, their kitchens should be fly-proofed, and the air filtered and sterilized. Thus installed in their operating theatres, these ideal food handlers would provide further touches of security for the proceedings by using aseptic techniques. There would be no rubbing of eyes, scratching of hair, or fingering of nose; and the food would not be coughed or sneezed into, sweated upon, talked at, or wept over. A visit to the kitchen of almost any contemporary eating-place will reveal what counsels of perfection such proposals represent." [45]

Though it may be impossible to follow this regimen in the institutional, restaurant, or household kitchen, some nearer approach to it than is now customary is quite feasible. Moreover, at least one health department regulation must here be added to the many previously discussed injunctions respecting personal hygiene and sanitation in the butcher's shop, restaurant, and home. No person with any cut, abrasion, boil, whitlow, impetigo, eczema, or other festering or discharging sore, should be permitted to handle meat for sale. The importance of such foci as potential sources of enterotoxigenic staphylococci is established, and health educators should stress to the public the enormous numbers of micro-organisms likely to be present in or near these trivial-seeming lesions. Another practicable requirement would be clinical and bacteriological examinations of the nose and throat of commercial food handlers. Any person showing signs, or known to have an epidemiological history, of being a heavy and persistent staphylococcal carrier [220] should be suspended from food handling occupations unless the organisms in his naso-pharynx can be shown to lack food-poisoning propensities.

When shopkeepers and householders have been enlightened about the main potential sources of infection, the exercise of plain common sense

can be expected to result in considerably improved protection of meats from staphylococcal contamination. For instance, covering meats under glass or plastic will greatly help to ward off droplets, dust, and flies. The frequent lack of simple fly-screens for doors and windows in butchers' shops has been indicted already as promoting *Salmonella-Shigella* infections. Staphylococci could be similarly fly-borne. Houseflies experimentally fed on a suspension of a food-poisoning strain of *Staphylococcus* were found to have these organisms on their feet and probosces 3 days later, while the same organisms survived in their digestive tracts for 8 days.[152]

(2) Several investigations have been made, chiefly in the USA, into the relationship of certain cooking procedures to staphylococcal food intoxication. Their main purpose was to determine the minimum heat exposure needed to destroy organisms present in such popular comestibles as cakes and pastries with cream or custard fillings, which become unattractive when excessively heated. In one report,[107] an enterotoxigenic strain of *Staphylococcus* survived in cream filling exposed for 30 minutes to 55°C, but was destroyed in less than 3 minutes of heating at 85°C. A recent report from England, where several outbreaks have been traced to reconstituted milk powder,[198] analysed the numbers of staphylococci present at various stages in the manufacture of milk powder by the spray-drying process. Intermittent heating for various short periods, including exposure to 175°F (79.5°C) for 10 minutes, with a final brief exposure to hot air at 310°-320°F (154.5°-160°C), usually reduced the count of viable staphylococci to about one-thousandth of the original figure.[104] Although staphylococci seem fairly heat-labile, of course some cultures may show more thermal resistance than others; indeed, erratic thermal-death-times have been recorded for a single strain.[90] The nature and consistency of the menstruum also markedly influence the results in such experiments. Meat pies, for instance, are likely to prove more difficult than milk to rid of viable staphylococci. Apparently there are no explicit data on this point, but the thermal resistance of staphylococci in meat pies is probably similar to that of salmonellae. From experimentally inoculated pies, *S. typhimurium* was recovered after baking for 30 minutes or less at 320°F (160°C), but not after 35 minutes of baking at this temperature; while *S. bovis morbificans* was recovered likewise after 50 minutes' baking, but not after 60 minutes'.[147]

Large joints of meat contaminated with staphylococci may be particularly difficult to sterilize by ordinary cooking methods. Fortunately, most pollution of meat carcasses by these organisms is relatively superficial and therefore amenable to heat; but if introduced into the deeper tissues from without by unclean instruments, as in the inoculation of hams with "quick-curing" solutions, they may survive conventional cooking processes, owing to meat's rather poor heat-conductivity. Enterotoxigenic staphylo-

cocci may even survive the heating to which some commercially canned meats are subjected. In England, a few outbreaks of food intoxication have been traced to tinned meats of Continental origin. In each episode the food had been eaten within 20 minutes after the tin was opened, and from this or companion tins staphylococci were isolated.[87]

In certain countries, such as Australia, the canning of hams has become an important industry, which has given rise to special risks of food intoxication. Elimination of any staphylococci present in the depths of these hams could probably be ensured solely by exposure to heat, provided this were equivalent to a central temperature of 65°C for 30 minutes, but there is an uncomfortably narrow margin of safety between the amount of heat essential to safeguard public health, and what the manufacturer will tolerate in terms of losses from shrinkage.[190] Similar difficulties are encountered in connexion with pre-cooked sausages and other ready-to-eat manufactured meats.

Traditionally, chemical preservatives have often supplemented or replaced cooking as means of hindering some of the many complex mechanisms involved in the microbial spoilage of meat.[112] Latterly, the so-called antibiotics have been suggested as additives to inhibit germination of pathogenic spores, and to prevent multiplication of bacteria involved in the various forms of bacterial food poisoning.[109, 130] In staphylococcal food intoxication and botulism, the inciting factors of which are toxins already formed in the foodstuffs at the time of ingestion, it would seem especially plausible to re-inforce the destructive effects of heat by bacteriostatic agents in order to prevent proliferation of any survivors. However, the available data indicate that such time-honoured chemicals as nitrites, nitrates, and sodium chloride exert no significant bacteriostatic effect upon *Staphylococcus* and *Clostridium botulinum* present in, for example, canned ham.[190] In fact, a food poisoning strain of *Staphylococcus* has been shown to grow well in salted chicken, ham, and beef tongues, containing 10% of sodium chloride.[118] As for the use of currently available antibiotics as bacterial inhibitors in foodstuffs, this would present numerous theoretical and practical pitfalls, such as irregular but generally waning degrees of bacteriostasis, selective survival of resistant organisms, and possible sensitization of the consumer.

There is general agreement that the heat stability of the enterotoxin is unusually high for this class of substance, since it is only partially destroyed by a temperature of 90°-100°C for 30 minutes.[51] Consequently, a foodstuff in which enterotoxigenic staphylococci have proliferated may remain toxic despite exposure to sufficient heat to kill all bacteria present. This principle obviously applies with even greater force to alternative methods of " preserving " meats, such as salting, curing, smoking, and drying, which are

less effective than thorough cooking in destroying staphylococci, and have no detoxifying action.

(3) The most widely accepted and effective mechanism for inhibiting bacterial growth and toxin production in foodstuffs is refrigeration. Some food poisoning strains of *Staphylococcus* multiply slowly at temperatures below 10°C but there is no evidence that significant amounts of enterotoxin can be elaborated in meats stored at such temperatures. Characteristically, large numbers of staphylococci (0.5×10^6 or more per gram) are found in foodstuffs implicated epidemiologically in staphylococcal food intoxication, although in certain circumstances the bacterial counts may be low.[45] The major control efforts should be directed therefore towards maintaining the bacterial population at the lowest possible level, not only during the period between slaughter of the animal and cooking of the meat, but also in the interval between cooking and consumption. Hence meats and meat products, at all stages of preparation and in all forms (including canned goods), should be kept whenever praticable in a refrigerator at a temperature not exceeding 10°C. Since intermittent exposures to warm indoor or outdoor temperatures encourage cumulative elaborations of enterotoxin, such exposures, whether on the kitchen table or in a picnic basket, should be as brief as possible.

In shops, restaurants, and households lacking refrigeration facilities, every effort should be made to keep meats cool by other devices. In addition, fuller emphasis must be placed on such control measures as avoidance of the multiplex sources of staphylococcal contamination, thorough initial heating, and curtailment of the respective intervals between slaughter, sale, cooking, and consumption of these foodstuffs.

Botulism

Mode of infection

The poisonous tendencies of blood sausage have been recognized in Europe for over 1000 years, judging by ancient edicts warning against their consumption. The peculiar form of neuroparalysis liable to follow eating such sausages was first accurately described in Württemberg in 1735; while the actual term *botulismus*, or sausage poisoning, appeared in the medical literature of southern Germany about 150 years ago. Public alarm had followed an outbreak in Wildbad, in 1793, involving 13 persons, of whom 6 died; this had been caused by consumption of a large sausage prepared by filling blood into a pig's stomach. Scientific interest was also aroused, and in 1820 the poet-physician Justinus Kerner published a treatise on botulism, giving details of the symptomatology and incidence of the disease, and asserting that in such disasters the noxious agent had

developed within the sausage, and was not some mineral or vegetable poison introduced from without. Soon afterwards, Kerner's work bore fruit : the local government made botulism notifiable, exact directions were given for the proper preparation of smoked sausages, and warnings were issued against eating them when spoiled.

The nature of this noxious agent remained controversial and unsuspected until 60 years ago, when Van Ermengem described the properties of an anaerobic, spore-forming bacillus which he had isolated from the rancid remnant of a raw salted ham.[213] The members of a musical society had refreshed themselves with this ham after performing at a funeral in the Belgian village of Ellezelles. Most of them had become ill with neuro-paralytic symptoms between 20 and 30 hours later : 3 died within a week, 10 others barely recovered, while several who ate lesser amounts of the ham suffered minor illnesses. The few who completely escaped had eaten only fat, or very small portions of the meat. The ham had been salted in customary fashion about 24 hours after slaughter of an apparently healthy pig, and had lain in the brine barrel for 11 days before consumption.

Culture filtrates of this anaerobic bacillus, when injected into various laboratory animals, produced characteristic and often fatal paralyses of cranial and peripheral motor nerves. Since these effects seemed identical with the human botulism syndrome, Van Ermengem named his organism *Bacillus botulinus*, and declared that an exotoxin produced in certain food-stuffs by this bacillus was responsible for the disease. After the turn of the century, the causal relationship of this bacillary toxin to the " sausage poisoning " of Germany (and also to the " fish poisoning " long recognized in Russia) was amply confirmed by European bacteriologists.

During the decades following the First World War, the chief advances in knowledge of the causation and prevention of botulism were made in the USA, where the fast-growing canning industry learned to its cost that botulogenic foods were not necessarily highly proteinaceous meats or fish. Indeed, in that country it soon became apparent that botulism was conveyed more frequently by vegetable than by animal products. Whereas in Germany over 80% of all recorded botulism outbreaks had been caused by sausages, hams and other meats, in the USA a similar preponderance was now evidently to be ascribed to canned vegetables and fruits. Moreover, although the case fatality rate from botulism was serious enough in Europe, ranging from 15% to 45%—an average of around 30%—in North America it was roughly twice as high. During the past half-century, the fatality rate in some 1400 cases of botulism recorded in the USA and Canada has averaged about 65%.[144] These developments led the United States Public Health Service to establish a Botulism Commission to review the epidemiology of the disease. As a result of the Commission's report,[45] the canning industry of California became subject to strict public

health regulations in 1925, almost exactly a century after Kerner's pioneer work had provoked compulsory notification of sausage poisoning in southern Germany. Moreover, the industry itself was stirred to support the extensive researches of Meyer and his associates into the distribution of the causal agents in nature, the resistance of botulinus spores to heat and other physical and chemical agents, and the factors conducive to toxin production. The information thus gathered and applied soon eliminated commercially canned produce as a significant source of botulism in North America. Further, the upsurge of interest in botulism in the USA was reflected in reawakened governmental concern in western Europe and the USSR to reduce the botulinic risks from such traditional vehicles as smoked, salted, and pickled hams or fish. On the whole, these efforts have been successful, despite set-backs and new hazards from shortages, carelessness, and haste engendered by the Second World War. Episodes caused by improper canning or preserving in the home still occur sporadically in various parts of the world, because the essential principles and sound techniques are still imperfectly grasped by the general public. The epidemiological features of these kinds of meat-borne botulism are illustrated in the following examples, reported within the past decade from Canada and France.

Occasionally, the almost neolithic dietary habits still prevailing among some Eskimoes result in disaster. For instance, in July 1945, at Markham Bay, in the eastern Arctic sub-division of the North-West Territories, 7 people died with typical symptoms of botulism after eating raw, or possibly parboiled, seal meat. The carcass had been kept on the ground inside a tent for a number of days. During mid-summer in this area, seals are usually shot from a boat, and stored unskinned in the family tents, chunks being sliced off as required. Alternatively, carcasses may be heaped on a pile on the shore for two or three days before being skinned and eviscerated. There are thus abundant opportunities for either endogenous (intestinal) or exogenous (soil) contamination. Since no attempt is made at this season to keep the seal meat on ice, a few days of warm weather may induce *Cl. botulinum* spores to germinate and manufacture lethal amounts of toxin. The Eskimo's liking for raw and slightly putrefied protein may thus be his undoing.[48]

In certain circumstances, decomposing foodstuffs are tolerated by less primitive people, sometimes again with tragic consequences. In September 1944, at Nanaimo, British Columbia, a man and his wife and their small son died of botulism about 24 hours after eating malodorous salmon which had been home-canned one year previously. From a companion tin of salmon, from a tin of chicken processed about a month before the outbreak, and also from garden soil in the chicken run collected four months after the fatalities, similar toxigenic strains of *Cl. botulinum* type

E were isolated. Numerous other organisms were present in the foul, partially cooked contents of these tins, while several unopened tins in the basement were blown. The man was unemployed, and had done the canning with very rudimentary precautions while his wife went out to daily work. The fatal supper, prepared by the man, was refused by two daughters, who escaped illness; but when the woman came home, she disguised the bad flavour with condiments, and the rest of the family ate the salmon. The canned chicken might have been served instead with the same end-result. This episode portrays

> " the extent to which simple motives and traits such as economy, obstinacy and undue solicitude for the pride of others in their small accomplishments, may together overcome both common sense and the elementary human impulse of revulsion against putrefying food ".[47]

Less tragic, though equally unnecessary, was the outbreak on a farm near Masefield, Saskatchewan, in May 1949, which involved the farmer's wife, her young daughter, a farm-hand and a hired girl, all of whom were hospitalized for botulism, from which they eventually recovered. The vehicle was home-canned beef, put up by the housewife four months previously. The meat, purchased from a neighbour, had been cut into small pieces and packed into large tin pails, which were then roasted in an oven for between two and three hours at 350°C. When the meat appeared to be cooked, the pails were removed from the oven, the lids put on, and melted wax poured over them. By the time public health officials launched an inquiry, the suspect can had been incinerated, but the woman was reticent about the condition of its contents. Several other cans were found in the basement with their wax seals blown. The contents of all were malodorous, and two were maggoty and overgrown with mould.[48] The more extensive heating applied in this instance was evidently insufficient to destroy some types of botulinus spores; and besides, the type of containers and method of sealing were quite unsuitable. Similar improvisations are doubtless resorted to in many rural areas of Canada and other countries.

Even satisfactory receptacles and prolonged boiling will not guarantee safe home-canning of meat. For instance, in October 1934, a man and his wife living near Orangeville, Ontario, fell ill with symptoms of botulism. They were admitted to hospital, where the man died, while the woman slowly recovered. Three weeks before their illnesses began, the man had shot a deer, which he skinned and cut up the next day. He gave some of the meat to neighbours, putting the rest in the cellar for two more days. This meat was then boiled in a pot for between three and four hours, and transferred while hot to quart sealers which had been boiled beforehand. During the next 18 days, successive jars of the meat were eaten

without harm by this couple and their neighbours. The victims opened their last jar, and consumed its contents, on the day before symptoms developed.[49] Although infection of a single jar conceivably occurred here in the course of transferring the boiled venison from the pot to the sealers, the episode more probably exemplifies two well-known epidemiological characteristics of botulism outbreaks. First, the important influence of time-lapse on toxin development; and secondly, the often irregular distribution of toxin within, for example, a ham or a large sausage, and among the various containers in a batch of home-preserved meats.

The outbreaks just cited illustrate the botulinic hazards arising from ignorant or careless preparation of temporary surpluses of meat in a vast, sparsely-settled country of varied customs and climates. If the resulting illnesses had been less grave, none of these episodes might have been reported; for it is generally conceded that cases and epidemics of mild and ambulatory botulism occur and pass undiagnosed. Of course, fewer instances are overlooked when local physicians and public health officials are especially alert to this possibility, as seems to hold in Germany and France. Botulism was rare in France before the occupation of 1940-44, perhaps because normally in that country few conserved foods are eaten. However, four years of food shortages so profoundly changed the dietary habits of the French people that over 1000 cases of botulism occurred. In no fewer than 150 of 205 episodes in which bacteriological examinations indicated the presence of botulinus bacilli or toxin, the vehicles were salted, smoked, or pickled hams, mostly home-preserved. Indeed, among a total of some 500 episodes, 465, or 93%, were due to pork meat. A remarkable feature of this upsurge is the very low case fatality rate of less than 2%.[131] Diagnostic acumen cannot wholly account for such slight mortality. Other contributory factors might have been the impossibility of prolonged storage; a common precaution of heating before consumption; and relatively low toxigenicity of the prevailing (type B) botulinic flora.

Before control measures are discussed, the main epidemiological features peculiar to botulism will be reviewed briefly and brought up to date. First, it is now evident that Van Ermengem's bacillus represented but one of at least five types—designated A to E—comprising the *Clostridium botulinum* species. Cultures of all these types may display toxigenic or non-toxigenic phases. The respective toxins exert qualitatively similar effects upon various experimental animals, from mice and monkeys to cats and goldfish; but these animal hosts display a wide range of susceptibilities to the various types of toxins. For instance, although types C and D toxins can cause serious epizootics among horses, cattle, or wildfowl, no human outbreaks have been ascribed to them. The only types known to be involved in human botulism are A, B, and E—the Ellezelles strain being probably type B. Toxigenic cultures of types A and B are

usually proteolytic, so that meat products in which they have grown are, as a rule, tainted ; whereas some European type B strains, and all toxigenic type E strains, are non-proteolytic and able to render meats (or fish) toxic without signs of spoilage. Regardless of the type involved, anaerobiosis is a prerequisite for spore germination, bacterial proliferation, and toxin production. *Cl. botulinum* thus differs from enterotoxigenic staphylococci in being unable to manufacture toxin on meat surfaces freely exposed to the air.

Secondly, there is general agreement that the botulinic syndrome, in animals and man alike, is basically due to preformed toxin in the material ingested. Neither atoxic botulinus cultures nor small doses of spores cause any apparent harm to laboratory animals. Very large numbers of spores injected intramuscularly into mice may germinate and produce enough toxin *in vivo* to cause fatal botulism ; but the danger to man from ingestion of spores in foods contaminated under natural conditions seems negligible.[119] Toxigenic cultures of *Cl. botulinum* may be present in the gastro-intestinal tract, and sometimes the viscera, of botulism victims (the organism was isolated from the spleen of a fatal case at Ellezelles, as well as from the implicated ham) but the invasive properties of these organisms appear to be entirely subordinate to their toxigenic activities in foods before consumption. In this respect, botulism resembles staphylococcal food intoxication, and contrasts with the food-borne infections.

Thirdly, a key factor in both the epidemiology and pathogenesis of botulism is the sporulating capacity of the causal agents. Indeed, a knowledge of the sources, natural habitats, and global distribution of these spores, and also of the conditions which promote or inhibit their germination, is essential to the control of the disease. The chief natural habitat of botulinus spores is the soil, and soil-polluted waters. The limited number of soil surveys carried out in a few countries show a general correlation between the telluric distribution of spore types and the recorded incidence of types A, B, and E botulism. Over 30 years ago, Meyer and Dubovsky found that the virgin soils of Pacific coast and Rocky Mountain states were particularly liable to contain type A spores ; and the majority of human botulism outbreaks in that area have been of type A origin, with soil-contaminated vegetables and fruits as predominant vehicles. On the other hand, in the intensively cultivated soils of the Atlantic states, and likewise of certain western European countries, botulinus spores were somewhat more sparsely distributed, the majority being of type B ; and this difference is also reflected in the incidence and types of botulism prevailing in those areas.[143] Again, within the past few years, several botulism outbreaks have occurred in Japan (where previously the disease was unrecognized), all of them fish-borne episodes caused by type E strains,

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which are demonstrably present in the sea-mud and lake-shore sands of Hokkaido.[156]

Such relationships cannot always be so readily discerned. For example, in the well-known disaster at Loch Maree, in the Western Highlands of Scotland—the only fully authenticated outbreak of botulism recorded in the British Isles—eight adults died in August 1922, as a result of consuming potted wild-duck paste, which was shown to contain *Cl. botulinum* type A and also highly potent toxin. Yet only shortly before, 64 soil samples from different parts of England had yielded 5 botulinus cultures, all identified as type B.[143] No doubt the irregular distribution of this disease throughout the world is governed by other factors besides the numbers and types of *Cl. botulinum* spores in regional soils, such as dietetic habits and culinary customs, the diagnostic acumen of the medical profession, the zeal of public health officials, and even the climate.

Finally, while the conception of the soil as a direct source of botulinic contamination of foods adequately accounts for most outbreaks caused by vegetables and fruits, it seems too narrow to cover meat-borne botulism. Where fish is the vehicle, the source of contamination is liable to be either exogenous or endogenous; and in the majority of such instances, the pathogenesis probably involves migration of vegetative forms (ingested by the fish as spores) from the gut through the intestinal mucosa into the surrounding muscles, where toxin formation occurs if conditions be propitious.[50] Similar conceptions applicable to meat-borne botulism have been slow in formulation, perhaps because of somewhat conflicting earlier evidence regarding intestinal excretion of spores by man and animals. The consensus now is that healthy persons normally do not carry botulinus spores in their intestinal tract or elsewhere; whereas some animals, particularly the pig and certain fish such as the sturgeon, are apt to be intestinal carriers. Botulinic pollution of pork may thus come about by exterior soiling, by absorption of organisms from the intestines into the blood-stream, or by migration of bacilli through the intestinal mucosa into adjacent muscles or viscera. After the experience with botulism of porcine origin in France just over a decade ago, Legroux and his co-workers [131] categorically asserted that pork flesh becomes botulogenic not through improper manipulations, but through infection of the animal's flesh via the blood-stream at the time of slaughter. They also claimed that some ante-mortem contamination of tissues resulted from an abundant digestive bacteraemia occurring in pigs slaughtered shortly after having been fed.

Control

The preventive principles already discussed for staphylococcal food intoxication also apply to botulism (though with changes in emphasis

and some extension) and may be reconsidered under the following headings :

(1) prevention of access of *Cl. botulinum* spores to meats ;

(2) destruction of spores, or inhibition of their germination, by heat and other physical or chemical agencies ;

(3) inhibition of bacterial growth and toxin production by refrigeration ;

(4) destruction of preformed toxin by heat.

The practicability of active immunization with botulinus toxoids is probably limited to persons at special risk.

(1) The chances of botulinus spores having access to meats are much smaller than in the analogous staphylococcal situation, since the sources of botulogenic contamination are practically restricted to the soil and to animal faeces. The problem of preventing spore contamination thus resolves itself mainly into a question of scrupulous slaughtering, butchering, and dressing techniques. Carcasses should be thoroughly and promptly washed, dehaired, and eviscerated, and the meet kept at all stages thereafter under dust-proof conditions. Special care should be taken to avoid conveying soil organisms by dirty hands or finger-nails to those types of manufactured meats in which anaerobic conditions obtain, such as large sausages and canned products. In meats exposed to the air, surface contamination with spores in itself can hardly cause trouble ; but occasionally the oxygen tension just beneath a meat surface could be low enough to permit germination to take place, so that motile vegetative forms of *Cl. botulinum* might find their way into deeper strata, where rapid multiplication and toxin production could begin.

The importance of avoiding contamination of meats by animal faeces applies, of course, to many other diseases besides botulism, and only two special points need be mentioned here. First, animal intestines to be used for sausage casings must be meticulously cleansed. Secondly, though it is still unsettled whether bacteria found in the blood, viscera, and muscles of freshly slaughtered animals reached there ante mortem, agonally, or post mortem,[112] the war-time epidemic of botulism in France was partly attributed to break-down of the practice of withholding food from pigs on the day before slaughter.

(2) The ecology of *Cl. botulinum* reflects both its anaerobic requirements and its sporulating capacity. Any handicap to free existence connected with the former property is retrieved by sporogenesis, which permits a few survivors of harsh environmental hazards to remain long in dormancy, whence they may be aroused eventually to proliferate and produce toxin. Destruction or inhibition of these spores is therefore a prime objective in the control of botulism. Heat, high concentrations of sodium chloride

and other electrolytes, and low pH values, are the agencies traditionally resorted to for these purposes.

Although complete destruction of all spores by heating would be more desirable than mere inhibition by chemical agents, the marked thermal resistance of some spores limits the extent to which sole reliance can be placed upon this measure. Type A spores may survive exposure to boiling water at 100°C for several hours ; type B spores are generally somewhat less resistant ; while type E spores are the most heat-labile of the human botulogenic types, being usually killed by exposure to 100°C for 30 minutes, and sometimes by as little as 5 minutes' exposure to 100°C.

The rarity of type E botulism outbreaks is no doubt largely due to the comparatively low thermal resistance of type E spores, which is such that even slight heating would generally suffice to destroy any of these spores present in a meat product. The apparent predilection of type E spores for uncooked fish and marine mammals is to some extent similarly explained.[50] However, there is no reason why partially cooked meat should not serve occasionally as a vehicle for type E botulism. In the Nanaimo outbreak, home-canned chicken was found to contain potent toxin and yielded type E organisms, although it was not implicated in the fatalities.

Again, the incidence of meat-borne botulism in Europe (where type B predominates) would inevitably be higher if type B spores were generally as heat-resistant as type A spores ; for the temperatures to which smoked sausages and hams are carried may suffice to destroy or inhibit many type B spores, while permitting type A to survive. Indeed, the Loch Maree tragedy probably would not have occurred if the causal organism had been type B rather than A. The materials composing the incriminated duck paste were all cooked in bulk and then heated in open receptacles in retorts ; and after the paste had been filled into small glass containers, it was again cooked at about 100°C.[132]

To guard against type A botulism by means of heat alone, meats must be brought to temperatures above 100°C. As most housewives know, foodstuffs can often be preserved merely by prolonged exposure in sealed vessels to 100°C. In fact, this was the basic principle of Nicholas Appert's experiments with bottled meats 150 years ago, and also of the tinned products which an English firm soon afterwards began supplying to the Royal Navy. One 4-lb. canister of roast veal, which formed part of the stores on Captain Parry's third voyage of 1824 to the Arctic in search of the North-West Passage, was opened in London 114 years later. Although the contents appeared perfectly normal, aerobic spore-bearing thermophilic bacilli were isolated therefrom.[110] Commercial canning became an established industry only after processes had been devised for applying temperatures above the boiling point of water, first by means of various chemical

baths, and later by super-heated steam. Condemnations on account of putrefaction were even then quite frequent, especially as a result of processing large tins of meat, which created heat penetration problems. About 35 years ago, however, the fast-developing California canning industry gave impetus to the determination of thermal death times for type A spores, which were found to range from 360 minutes at 212°F (100°C) to just under 3 minutes at 250°F (121°C). More recent work in this field has emphasized that the spore-suspending medium markedly affects these determinations.[199]

As a result of such laboratory investigations, manufacturers nowadays can refer to tabulated data on the heat requirements for safeguarding the public against the botulinic hazards of a great variety of foodstuffs in several sizes of cans;[2] and reputable firms are very seldom involved in botulism episodes. However, licences for sale of canned produce should not be issued to small firms with meagre resources, who seem unable or unwilling to comply with these standard heat requirements. For home-canning, health departments should advocate the use of pressure cookers of reliable make, and should stress that in places at higher altitudes, where boiling-water temperatures may be well below 100°C, the exposure times must be extended.

Some meats, such as canned hams, cannot be heated beyond a certain point without shrinkage or other commercial disadvantages. Similar difficulties tend to govern the processing of certain kinds of sausages and manufactured meats. In such instances, additional security is sought from the use of sodium chloride and other salts, whose inhibitory effects upon spore germination, bacterial growth, and toxin production have been studied extensively. The consensus is that 8%-10% NaCl in pickled meats ensures against botulism; but this is about twice the amount commonly present in mild-cured canned hams.

In addition to sodium chloride, the nitrite is commonly present in canned hams to a concentration of 30-100 parts per million (p.p.m.), but even the maximum concentration of 200 p.p.m. permitted in most countries is apparently insufficient to prevent the growth of *Cl. botulinum*. Sodium or potassium nitrates are also present in canned hams in concentrations ranging from 0.1%-0.5%; and again, though the evidence is somewhat conflicting, there is no assurance that these concentrations *per se* are inhibitory to germination of botulinus spores.[190] For many years it was held that marked acidity of a foodstuff almost automatically rendered it non-botulogenic. However, occasionally botulism has been traced to foods whose pH was 5.0 or less; and the typical pH range for canned hams is 5.5-6.2.

Although bacteriostatic factors such as the foregoing may be individually ineffective, suitable combinations of heat and chemical preservatives may

eventually become definable which prevent spore germination in all circumstances. Meanwhile, both the need for stringent anti-botulinic precautions and the limitations of currently practised measures seem to be insufficiently realized. The disquiet felt on this score by a comparatively small group of bacteriologists and food technologists has led some of these experts to advocate use of antibiotics in the preservation of meat, despite the many public health and medico-legal problems inherent in such proposals.[109, 130] Others have pressed for further research on the bacteriological merits and demerits of the newer types of processed foods, for example, dried or frozen meats, and on the public health aspects of methods as yet only in the experimental stage, such as electronic sterilization.[158] A considerable literature on dried meats [124] testifies to the urgent need for appropriate bacterial standards, since many pathogens, including salmonellae, enterotoxigenic staphylococci, and *Cl. botulinum* spores, can survive in sufficient numbers in dehydrated meats to flourish and become a menace when the food is reconstituted and kept under suitable conditions.[80]

(3) Some strains of *Cl. botulinum* grow very well and produce toxin at ordinary room temperatures around 20°C, while slight toxin production by certain strains has been demonstrated at 10°C. At the average temperature of a household refrigerator, around 5°C, neither growth nor toxin production occurs. The refrigeration of all potentially botulogenic foods is therefore a sound precaution. Scott [190] even urges the cold storage of such foods as canned hams in order to inhibit growth of organisms not destroyed by the heat process. On the other hand, botulinus spores seem practically unaffected by freezing, while the toxins are very stable at low temperatures. Spores could thus survive for months in the many types of frozen foods (precooked and otherwise) now on the market, only to germinate and multiply when the foods are thawed, provided anaerobic conditions prevail. Moreover, even deep-frozen foods are not necessarily safe if there have been opportunities for toxin production either before the food was refrigerated or after it began to thaw. The need to exercise scrupulous care at all stages in the preparation of such foods, and to develop bacteriological standards by which to assess their quality, is very evident.[94, 173]

(4) Whereas some strains of botulinus spores are extremely resistant to heat, vegetative forms of *Cl. botulinum* are killed within 10-15 minutes at 80°C. Botulinus toxins are even more heat-labile, in this respect contrasting with staphylococcal enterotoxin. Over 30 years ago, Schoenholz & Meyer [188] showed that types A and B toxins in fluid nutrient media were destroyed in about 6 minutes at 80°C. Thorough exposure of botulinic foodstuffs to the temperatures of boiling water should therefore eliminate all danger from preformed toxin. Of course, full allowances must be made for the differences in permeability to heat of the various foods and

receptacles. The numbers of lives spared through observance of this simple precaution cannot be estimated, but during the German occupation of France its efficacy in averting botulism was, on occasion, vividly demonstrated. For example, salted ham which had developed a suspicious butyric odour, and in which botulinus organisms and toxin were demonstrable, was eaten by some 200 persons in an institution without any ill effects. The ham had been cut into thin slices, which were placed in the heat released by a dish of hot vegetables, before being served.[131]

Housewives would do well to adopt the habit of routinely heating all home-canned foods before consumption. Preserved foodstuffs of whatever origin showing the slightest sign of spoilage, if not thrown away, should be similarly treated. To take advantage so simply of the fortunate heat-lability of botulinus toxins seems a small price to pay for safety.

Miscellaneous Forms of Bacterial Food Poisoning

At least one-third of food poisoning outbreaks are diagnosed on clinical and epidemiological grounds alone. Among the factors responsible for failure to identify the etiological agent are faulty selection of food samples for laboratory tests, the use of inappropriate media and isolation techniques, and overgrowth of cultures by contaminants. Further, although occasionally some organism is demonstrably present in pure or predominant culture in a suspect foodstuff, the public health laboratory may feel impelled to dismiss the findings as of no particular significance for one of the following reasons.

First, the organism in question may be accepted as a pathogen in certain circumstances, and yet be so widely distributed as to seem an almost unavoidable contaminant, especially in foods which have taken some hours to reach the laboratory. This was the main reason for delayed recognition of staphylococcal food intoxication as an important entity, and partly accounts for continuing uncertainty about the food poisoning potentialities of streptococci. Secondly, the organism and its metabolites may be known to exert pathogenic effects through established portals of entry, which tend to overshadow entirely different properties displayed only upon ingestion. This tendency again played a part in connexion with staphylococcal enterotoxin, and has also influenced appraisal of the food poisoning role of *Clostridium perfringens* (*welchii*). Thirdly, the organism may be both uncommonly encountered in public health laboratory practice and unrecognized as pathogenic by any route; in which event (as with *Bacillus cereus*) claims of food poisoning propensities are liable to be viewed sceptically. Despite these reservations, specific forms of food poisoning are now generally believed to be caused by certain strains of

Cl. perfringens, *B. cereus*, and *Streptococcus*, the epidemiology of which will be briefly discussed in turn.

Clostridium perfringens (welchii)

Since 1895, the isolation of sporulating anaerobes from the faeces of patients in diarrhoeal outbreaks has been reported intermittently. However, bacteriologists have been reluctant to ascribe enteritis to an organism frequently found in the faeces of normal persons and animals. Similar difficulties postponed the attribution of food poisoning properties to organisms often present in various kinds of foodstuffs, from milk and cheese to fish and whale meat. During the Second World War, however, when food sanitation problems multiplied because of changed cooking and eating habits in many countries, attention was repeatedly drawn to outbreaks of intestinal disturbances traced to meats heavily contaminated with anaerobic spore-bearing bacilli. For example, in 1943 several outbreaks of this type, in which warmed-up gravy was the apparent vehicle, affected schoolchildren in England.[123] Soon afterwards, steamed chicken contaminated with *Cl. perfringens* was incriminated in a series of four food poisoning outbreaks in the USA.[136]

Over the period 1946-48, a number of cases of haemorrhagic enteritis, or "enteritis necroticans", were noted in northern Germany. From portions of intestines removed both surgically and post mortem, and from the faeces of a typical case, *Cl. perfringens* was isolated. These cultures were designated type F, because although they resembled type B strains in producing chiefly the B-toxin, they differed in other respects, notably in the high thermal resistance of their spores, which were able to withstand boiling for from one to four hours.[224] In one episode of this kind, three persons developed gastro-intestinal disturbances a few hours after eating tinned rabbit of which the appearance and odour were wholesome. A man aged 71 died some 50 hours after the onset of abdominal pain, severe vomiting and diarrhoea, while the other two persons had mild and transient symptoms. *Cl. perfringens* type F was isolated from the faeces and intestine of the fatal case, from the faeces of another case, and from remnants of the rabbit meat. This meat had been tinned immediately after the butchering of home-bred rabbits about three weeks before; the tins had been boiled (with lids closed) for two hours in a water-bath. A contemporary survey conducted on 108 faecal specimens from inhabitants of Hamburg showed type F strains to be present in 19, or 17.5%; but these were much less pathogenic for animals than the strains isolated from cases of enteritis necroticans.[92]

In 1952, Oesterling reported that in 15 out of 33 food poisoning outbreaks occurring in Sweden during a two-year period, the predominant

organism had been *Cl. perfringens*. In seven instances, the isolated strains were inoculated into foods corresponding to those whence they came, and were fed thus to volunteers, who developed mild diarrhoea.[160] Soon afterwards, Hobbs et al. summarized the epidemiological and bacteriological data on 23 outbreaks of food poisoning investigated in the London area over a period of one-and-a-half years, in which the agent suspected was *Cl. perfringens*.[105] Characteristically, these outbreaks were caused by meat which had been boiled, braised, steamed, or stewed for from two to three hours, allowed to cool slowly overnight, and eaten cold or warmed-up the next day. (These authors claimed that " roast meat is seldom incriminated ", and also that " a large proportion of the persons at risk were usually affected ". However, in an otherwise typical hospital outbreak,[12] warmed-up roast pork was the proven vehicle, and only 44 persons were affected out of some 360 at risk.) Colic and diarrhoea, usually without vomiting, appeared 8-22 hours after the infected food had been eaten, but recovery was usually complete within one or two days. Incriminated meats were unaltered in appearance or smell at the time of consumption, although when received for laboratory examination some samples smelled sour and showed gas formation. Direct anaerobic culture of implicated food samples generally showed heavy growth of *Cl. perfringens*. In most respects, these cultures were classifiable as type A ; but they were atypical in being non-haemolytic on blood-agar plates, and in the high thermal resistance of their spores. Similar strains could be isolated from the faeces of about 90% of patients and individuals at risk, but from only 5% of normal persons, or of persons with other diarrhoeal illnesses. Again, these organisms were present in 15%-25% of faeces samples from pigs, rats, and mice, and also in samples of raw beef, pork, and veal. Moreover, several batches of trapped blowflies all carried heat-resistant strains of *Cl. perfringens*.

There appears now to be general agreement that meat dishes left overnight in a warm room, or repeatedly warmed up and slowly cooled, may provoke an enteritis caused by rapid proliferation of organisms derived from a few heat-resistant spores of *Cl. perfringens* which survived the original cooking. Several questions remain unsettled, in particular the respective parts played in this food poisoning syndrome by ingested living organisms, by preformed toxins, and by toxins elaborated within the intestine after consumption of infected food. Experiments on human volunteers to date have been too limited in scope to determine this issue,[39] while laboratory animals apparently do not react under comparable conditions. The epidemiology seems, however, to be sufficiently established to permit the principles of control to be briefly stated.

First, since heat-stable spores of *Cl. perfringens* are relatively common in human and animal faeces, their transfer to meat can be avoided only by excercising all those precautions advocated against excreta-borne

infections. Meats must be safeguarded in the abattoir, and at all stages thereafter, from direct or fly-borne pollution with animal faeces. Human pollution is to be averted by scrupulous personal hygiene, especially hand-washing, on the part of food handlers.

Secondly, growth of these organisms and their metabolites must be minimized by careful attention to temperature control. Where possible, meat dishes should be freshly prepared just before consumption; but when cooking of large quantities several hours beforehand is unavoidable, the heating must be thorough. Heat penetration (and subsequent cooling) is encouraged by using small joints in preference to large ones. Types A and F spores sometimes exhibit a thermal resistance of the same order as *Cl. botulinum* type A spores, against which only the pressure cooker can prevail. Until this device for rapidly destroying spores is popularized, reliance will have to be placed upon keeping cooked meat either too hot or too cold for appreciable bacterial growth. In other words, the meat should be passed as rapidly as possible through the range of warm temperatures optimal for spore germination and bacterial multiplication. Once cooked, meats must be cooled quickly, preferably on shallow trays in an air-conditioned room, and then refrigerated.[85] If re-heating is necessary, this should be done just before the meat is served.[105]

Cl. perfringens outbreaks have been connected mostly with canteen meals and other systems of communal feeding initiated during the Second World War. Such arrangements have probably come to stay, and it is therefore important that safe patterns for large-scale food preparation under these conditions be worked out in detail along the lines indicated above.

Bacillus cereus

Over the past half-century, aerobic sporulating bacilli (seldom specifically identified) have been reported now and again, chiefly from Germany and Sweden, as the cause of mild food poisoning outbreaks. During the period 1947-49, Hauge identified *Bacillus cereus* as the cause of four institutional outbreaks of food poisoning in Norway, involving altogether about 600 persons. Since then, Scandinavian countries have reported similar outbreaks, which have resembled those caused by *Cl. perfringens* both in symptomatology and in some epidemiological respects.[96] For instance, the spores of *B. cereus* survive moderate heating, so that vegetative forms may multiply rapidly in suitable pre-cooked food left to cool slowly in massive quantities, as is apt to occur in institutional kitchens.

Whereas meat dishes have been associated characteristically with *Cl. perfringens* outbreaks, the customary vehicles in *B. cereus* outbreaks have usually been starchy foods, and more particularly vanilla sauce.

These organisms are widely distributed in soil, dust, and plants, and presumably gain access to the implicated foodstuffs from such sources. Although so far *B. cereus* has not been incriminated in outbreaks with meat as vehicle, it could be conveyed readily to meat from some ingredient in the pastry of a meat pie. Recently, in a western Canadian city, when complaints of mild abdominal disturbances attributed to fancy sausages were followed up, laboratory tests showed large numbers of *B. cereus* in similar sausages and in a potato-flour ingredient.

The syndrome has been reproduced in volunteers by administering foods inoculated with *B. cereus* cultures isolated from outbreaks; but the results of such experiments are often equivocal, and have sometimes proved entirely negative.[39] Hauge claims that a preformed enterotoxic substance produced in the food accounts for the sudden onset and relatively short duration of the illness. However, culture filtrates of *B. cereus*, like those of *Cl. perfringens*, apparently do not produce food poisoning symptoms in volunteers.

The prevention of this condition depends mainly upon preparing susceptible foods a short time before serving. If storage after cooking cannot be avoided, the food should be rapidly cooled to a temperature low enough to inhibit multiplication of these mesophilic bacilli. Trouble seldom occurs where health authorities have issued instructions along these lines.

Streptococcus

Although there seems little doubt that certain strains of *Streptococcus* are able to cause food poisoning, and that meat can serve as a vehicle, surprisingly few outbreaks have been described in view of the wide distribution of this organism. Moreover, the literature shows many discrepancies in symptomatology, in the types of streptococci allegedly involved, and in the results of administering live cultures and sterile filtrates to laboratory animals and human volunteers. Part of this confusion can be resolved by conceding that only certain cultures of either green-producing or β-haemolytic (group A) streptococci can provoke food-poisoning syndromes, through the ingestion of different preformed toxins. The comparative rarity of streptococcal food poisoning, and likewise the irregular responses of man and animals to experimentally ingested cultures or filtrates, then become more explicable; for the toxigenic properties of many streptococcal strains *in vitro* are very complex and fickle, while host susceptibility to at least one of these toxic agents—the erythrogenic (Dick) toxin—is known to be extremely variable.

The exact nature of the postulated streptococcal enterotoxic substances, and the conditions requisite for their manufacture in foods, remain

indefinite. In the human feeding experiments conducted by Osler et al.,[163] various foods inoculated with broth cultures of *Str. faecalis* were administered to 26 persons, of whom only 6 developed gastro-intestinal disturbances after an incubation period of 2½-10 hours. No definite food poisoning symptoms followed when the same volunteers were given varying amounts of 20-hour cultures of *Str. faecalis* grown in milk or broth. Of the four streptococcal strains tested, only two provoked illness. One of these had been isolated recently from human faeces, and the other about a year before from evaporated milk implicated in a food poisoning episode. The rather wide range of incubation periods may derive partly from different host susceptibilities, and partly from the various potencies of the enterotoxic substances ingested. Where the potency is high, action upon the stomach might induce early vomiting, with consequent elimination of enterotoxic material; whereas less powerful doses might pass through the stomach, with little apparent effect until they reach the lower bowel and provoke diarrhoea.[150])

The first meat-borne outbreak of food poisoning ascribed plausibly to faecal streptococci was reported in 1931 from the USA.[23] Canned wiener sausages were served at an institutional supper to 182 boys, of whom 75 suffered gastro-intestinal disturbances. One volunteer suffered nausea, vomiting and abdominal pain five hours after eating half a sausage from each of four freshly-opened cans from the same batch. Another person developed similar but less definite symptoms after drinking 40 ml of a non-sterile Berkefeld filtrate of five-day broth cultures of the implicated streptococcus; but a third volunteer drank 50 ml of a sterile filtrate with no ill effects. There are various possible explanations of such results.[39, 150]

From the same laboratory, seven years later, came a report of another outbreak in which roughly one-half of a group numbering about 250 young men became ill, with diarrhoea the outstanding complaint, some hours after a noon meal of veal croquettes.[22] After each of three previous evening meals, left-over meat scraps were kept at room temperature overnight in a large container, and then refrigerated until minced to make the croquettes. These were fried in deep fat for 10 minutes at 110°C—an insufficient heat exposure to destroy the large numbers of streptococci (and presumably their accompanying toxic metabolites) beneath the surface of the meat.

Recently, Moore has reviewed other food poisoning outbreaks of purported streptococcal origin.[150] Meat and milk products have been the customary vehicles, and faecal types of α-haemolytic streptococci have predominated as apparent causal agents. In two instances, the numbers of such organisms present in the incriminated ham and beef were estimated respectively as 3.5×10^6 and 4.5×10^6 per gram. Incidentally, since the classification of *Str. faecalis* is still indefinite, the source of these food

poisoning strains is not necessarily faecal. For instance, in one outbreak in the USA, 18 persons became ill after eating creamed chicken in a war industry canteen. Group B streptococci were isolated in pure culture from remnants of the chicken and from the throat of a food handler.[76]

Until pasteurization of milk and milk products was widely adopted, disastrous outbreaks of scarlet fever, septic sore throat, and other haemolytic streptococcal diseases, testified to the capacity of group A streptococci to provoke food-borne infections and toxaemias. During the Second World War, several large epidemics of apparently food-borne haemolytic streptococcal diseases occurred, in which milk could be ruled out as vehicle. In a few of these outbreaks, group A streptococci of the same types were isolated from the suspect food and from the nose and throat of a person preparing the food. Such episodes have generally not been meat-borne, but one exception deserves mention. Ground ham served in a war industry canteen was epidemiologically implicated in an outbreak of 24 cases of scarlet fever and 56 cases of streptococcal sore throat. A type 2 strain of *Str. haemolyticus* group A was isolated from the ham and from the throat of a food handler.

The main sources of food poisoning strains of *Streptococcus* are apparently human (or animal) faeces, and the nose, throat, or infected skin, of handlers. The control of streptococcal food poisoning is therefore ensured by a combination of those hygienic measures already detailed for the prevention of staphylococcal food intoxication and of excreta-borne infections. Recapitulation is unnecessary, but two points merit special emphasis. First, persons with evident sore throat, impetiginous rashes, or erysipelas, should obviously be barred from food handling. Secondly, though the enterotoxic substances elaborated by some strains of rapidly proliferating streptococci appear less heat-stable than staphylococcal enterotoxin, they are relatively resistant to light cooking processes. Once again, therefore, if streptococcal food poisoning is to be averted, cooking processes must be especially thorough, and supplemented by prompt refrigeration of all meats before and after heating.

CONCLUSION

A fairly thorough exposition has been attempted of the various routes and mechanisms by which diseases may be meat-borne. The epidemiological peculiarities of these diseases have received due emphasis in the different sections of the adopted classification ; by way of conclusion, perhaps a few brief reflections are pertinent.

In its hunger for animal protein, humanity is exposed to a formidable array of potential hazards. The laws of chance, various specific immunities, and the alimentary juices, generally carry the individual through each day without harm from the food he eats. But the odds are being weighted against him by the drastic changes in feeding habits occurring in most civilized communities. As Wilson has lately pointed out:

> "In the communal kitchens practices have been taken over from the home which, though unobjectionable when applied to small quantities of food, present dangers of their own when large masses of food are being handled. In addition, a great variety of foods, cooked and uncooked, processed and unprocessed, contaminated to some degree with potentially dangerous organisms, have been coming on to the market and causing not only food poisoning but a wide dissemination of infective materials among the human and animal population." [219]

Indeed, in due course, the inescapably growing propinquity of mankind, and the intimate intermingling of man with animals, may create new types of danger to health through our food supply which will baffle scientific ingenuity.

Nevertheless, it is not new scientific discoveries that are needed to lessen the waste and misery due to meat-borne diseases—or to most other groups of diseases—but rather the effective dissemination and application of currently available knowledge. Of course it is desirable (and unavoidable) that research workers should continue, for example, to uncover hitherto unsuspected animal reservoirs of potential human disease; to investigate the germicidal efficiency of various forms of irradiation applied to foods; and to develop new detergents for cleaner washing of restaurant utensils. Meanwhile, nevertheless, in some parts of the world where poverty is rampant and tradition sanctions custom, animal dung may be used for building houses, for cleaning floors, and for cooking food. In far wealthier countries, millions of people daily consume food contaminated with human faeces through the inadequately washed hands of those who serve them. Certainly we cannot deplore the ignorance which endorses the former state of affairs and yet condone the carelessness and laziness governing the latter. Instead, it is fairer and better to recognize that there is room for broadcasting knowledge and awakening conscience in respect of those two fundamentals for reducing the toll of meat-borne diseases—temperature control, and cleanliness.

Obviously, this entails a problem of education at all levels, supported by law enforcement. The microbiologist, parasitologist, epidemiologist, and veterinarian must know their business thoroughly, and should stand ready to impart relevant information, patiently and lucidly, to intermediaries trained to pass it on intelligibly and convincingly to the general public. In turn, practising physicians, medical health officers, public health

nurses, sanitary inspectors, health educators, and hygienists of every kind must relay the necessary facts to the layman, devise regulations to guide him, and be unhesitant in checking upon performance, seeking encouragement from faith in Disraeli's dictum: "The health of the people is really the foundation upon which all their happiness and all the power of the State depend".

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Part II

ANTE-MORTEM CARE

TRANSPORT, ANTE-MORTEM CARE, AND INSPECTION OF ANIMALS INTENDED FOR SLAUGHTER

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Meat hygiene may be defined as expert supervision of all meat products with the object of providing wholesome meat for human consumption and preventing danger to public health.

Inspection of meat has two aspects : examination of the live animals on entry to the slaughterhouse (ante-mortem inspection), and examination of the carcass and any food products made from the meat after slaughter (post-mortem inspection).

Ante-mortem Inspection

Of the two, the most important is the ante-mortem inspection, without which no adequate inspection of the carcass or meat is possible. There is no need in that connexion to specify the diseases found in domestic animals in which anatomical changes are slight in comparison with the severe clinical symptoms (notably, septicaemia) ; paratyphoid may be regarded as one of the most dangerous of these to the health of man. In cases of emergency slaughter or slaughter of sick animals, too, it is difficult for the meat inspector to form his judgement without ante-mortem inspection. Again, transportation affects the condition of the slaughter animals, exciting or tiring them to a greater or lesser degree according to the type of transport and the length of the journey. This, in turn, has a direct influence on the keeping qualities of the meat and, without ante-mortem inspection, there is no possibility of holding up slaughter pending recovery.

Ante-mortem inspection ought to be carried out solely by veterinarians, and these should preferably have had a long experience of general clinical practice before taking up this type of work. Furthermore, it should be veterinary inspectors who deal with all animals marked down as suspect at the ante-mortem inspection. In many cases the judging of such animals is difficult, even for scientifically trained men ; it frequently proves a hard test of their knowledge and skill.

The amount of weight placed on the ante-mortem inspection varies from country to country. In the Netherlands, for example, no animal is condemned outright on the findings of this inspection alone. In the USA, on the other hand, any animal showing on ante-mortem inspection symptoms of rabies, tetanus, milk-fever, or railroad sickness is immediately condemned and subsequently consigned to the offal tank. Obviously, the need to protect the public against the danger of consuming diseased or unsound meat must always be the primary consideration. Nevertheless, the importance of avoiding wastage of valuable meat and meat products requires that only those animals that are totally unfit for human consumption should be wholly condemned. Hence, the correct procedure in such cases would be to conduct a post-mortem inspection, supplemented by the requisite bacteriological tests, before forming the final judgement.

Emergency slaughter and slaughter of unsound animals

Immediate killing is sometimes necessary where an animal is so injured or sick that death is inevitable. It is important that such animals should be slaughtered at the earliest possible moment, in order to save the meat for human consumption.

Where an animal already dead is brought to the abattoir, irrespective of the hour of arrival, a microscopic examination of blood taken from a subcutaneous vein should be made immediately. The carcass should be left untouched until this has been done.

Where an animal has been involved in a serious accident or is a potential danger to life or property, it is, of course, not always possible to carry out an ante-mortem inspection.

In cases of emergency slaughter or the slaughter of a " suspect " animal, the temperature should always be taken.

Transportation and Ante-mortem Care of Slaughter Animals

Animals may be moved from one place to another by any one of the following means:

(1) driving on the hoof;
(2) road transport;
(3) rail transport;
(4) sea transport.

As a rule, slaughter animals are not carried by air with the exception of hogs, as this means of transport tends to be rather costly. The internationally accepted standards adopted by K.L.M. (Royal Airways Company) of the Netherlands are reproduced in Annex 5, page 381.

Moving of animals, whether by driving on the hoof or transportation by rail or by any other means, will cause a change in their physical condition. This change is always evidenced in the quality of the meat. Fractures, bruises, and such-like injuries may be incurred, and suffocation is a further risk with which all transport companies are familiar. Furthermore, no consigner of cattle overlooks the loss of weight that is caused by transportation, whatever its nature.

Driving on the hoof

When driven over short stretches of road under favourable weather conditions, animals will show no sign of physical strain on arrival at the place of destination, provided they receive proper treatment *en route*. Apart from the inhumane aspect—and most countries have legislation against cruelty to animals—all unnecessarily cruel practices to keep the animals on the move should be condemned because of the effect on the quality of the meat.

Road transport

Road trucks for the transportation of animals should be specially built for the purpose and should be adapted to the different kinds of animal. Provision should be made, too, for easy loading and discharging.

FIG. 1. TRANSPORT TRUCK FOR SHEEP, WITH TWO FLOORS : I

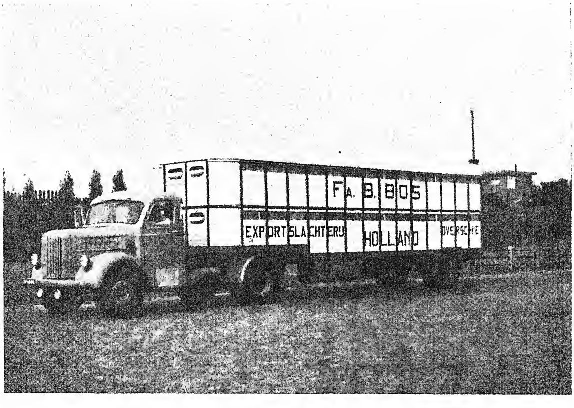

FIG. 2. TRANSPORT TRUCK FOR SHEEP, WITH TWO FLOORS: II

Regulations governing road vehicles for the transport of animals are in force in the Netherlands (see Annex 2, page 370), the object of which is to lay down hygienic requirements that will safeguard the animals against unnecessary suffering during transportation and ensure arrival at the destination in the best possible condition. Other European countries appear to have regulations on very much the same lines.

The cattle trucks that have been built to these requirements generally appear to be excellent. One special design in the Netherlands has a trailer accommodating 80-100 cattle and has a special compartment for attendants and spare drivers. For the transport of the smaller animals, such as pigs and sheep, a special type of truck has been devised with two or more decks to economize in space (see Fig. 1, 2). Incidentally, there is an Australian sheep-truck that has several trailers and can transport 800-1000 sheep at a time.

On humane grounds, animals conveyed by truck should not be fettered unless there is a risk of their jumping out; tying of the legs of small animals should not be permitted either. It is very foolish, too, for consigners to try to economize on freight by overcrowding. The risk of suffocation and injury to the animals is greatly increased.

Road transportation of animals has a number of advantages over transport by rail. It is much quicker, since trucks can move from point to point by the shortest direct route, cutting out the deviations necessitated by rail. For this reason, many European countries favour transport by road. Unfortunately, up to the present, all efforts to set up international standards for the road transportation of livestock have failed, despite the obvious desirability of such measures within Europe.

Rail transport

Special wagons, developed in the light of experience over many years, have been devised in the Netherlands and elsewhere to meet the requirements of this type of transport for animals. The size of the wagon is prescribed; proper ventilation is ensured; and feeding and watering arrangements have been perfected. In the USA, the transport of cattle is mostly effected by rail. In view of the immense distances to be covered and the capital value of the consignments, the stockbreeders must be assured that the animals will arrive at the destination in good condition. Consequently, the railway companies have special departments dealing with cattle transportation. Special wagons have been built to fit the transit platforms, so that a long cattle-train can be serviced quickly. Rail transport of animals in Europe, on the other hand, is negligible. The regulations governing rail transport of animals in the Netherlands are reproduced in Annex 3, page 372.

United States law requires cattle to be unloaded and rested every 28 hours; the only exception is where the total duration of the journey does not exceed 36 hours. Transport is effected in the following way. Local wagons are taken to one of the nearest main railway lines. There, a cattle train is made up and dispatched on an express schedule to one of the special transit centres, where the wagons are handed over to a forwarding company for dispatch to the central markets. To avoid exhaustion, it is regarded as essential that the animals should be given humane

treatment and care during transportation. Otherwise, the meat will deteriorate and even the skins will lose in value. The National Live Stock Exchange has issued valuable advice for stockholders and farmers, concerning :

(*a*) preparation of wagons for conveyance of cattle ;

(*b*) classification of different kinds of cattle and separation of dangerous animals ;

(*c*) employment of experienced livestock attendants, familiar with the various peculiarities of animals and their transport.

The United States Department of Agriculture further recommends that pigs in transit in hot weather should be placed in a well-ventilated place for some time before the train leaves, in order to cool off. Loading should not be permitted earlier than one hour before departure time. Regulations in the USA are also very strict concerning the state of health of animals. Some of the States require a certificate of health stating that cattle to be transported are free from tuberculosis ; exemptions from this rule are permitted for animals in transit through intermediate States. The same formality is also required for pigs, in some cases to be supplemented by a certificate that no contagious diseases, or symptoms of such diseases, have been observed in the area of origin. For the purpose of scabies control, it is a frequent requirement that sheep should be dipped under veterinary supervision within the ten-day period preceding transport, the dipping to be repeated within 10 days of arrival at the place of destination.

Considerable loss of weight during transport, or " shrink " as it is called, may be caused by faulty transport methods, but there are many other factors which will give rise to loss of weight, notwithstanding adequate feeding arrangements : for instance, rough handling, a change in weather conditions, or other more or less important causes that cannot always be eliminated.

It has been established by the United States Department of Agriculture that feeding during transportation has a great influence on the amount and duration of the shrink. In the case of cattle under transport, the shrink may amount to :

2.05% - 3.91% in 24 hours
3.45% - 5.40% in 24-36 hours
3.88% - 6.37% in 36-72 hours
3.96% - 7.00% in 72 hours

An interesting investigation, reported by Hanfland,[3] on the shrink in the live weight of cattle during transportation was carried out over a three-year period by the United States Bureau of Animal Industry. The investigation yielded the following information :

(*a*) The shrink in cattle during transport depends upon various factors, including:

(i) the condition of the animals at the time of loading and the kind of treatment received during the drive to the place of loading;

(ii) the length of time between the last feed and loading;

(iii) the kind of food the animals are given before loading (when grass or sugar-beet was fed, a greater loss of weight was observed);

(iv) the weather conditions prevailing at the time of loading and during transportation;

(v) the kind of transport to the market (if conditions are not good, the loss of weight will be greater);

(vi) the kind of treatment during halts at the stations in transit;

(vii) the time of arrival at the market. (The loss of weight will be considerable if the animals have to cover a great distance on the hoof after arrival at night. On the other hand, if they arrive during the afternoon or on the eve of market day, they can be rested and fed.)

(*b*) The shrink in calves may appear to be small; under normal conditions, however, this will be in the same proportion as the shrink in full-grown animals.

(*c*) The difference in shrink between bulls and cows is not as great as is generally supposed, but bulls do not shrink as much as cows of the same weight.

(*d*) The shrink during the first 24 hours of transport is relatively greater than during the following 24-hour period.

(*e*) The shrink in cattle is in direct proportion to the live weight, provided that all conditions and factors are the same.

(*f*) Cattle shrink is about 5%-6% of the live weight for a period of transportation lasting 70 hours. During transport for 36 hours or less, the shrink is 3%-4%.

(*g*) Fat animals, fed on sugar-beet, shrink more than normal cattle during transport, and consequently show a greater net shrink.

(*h*) The shrink diminishes proportionally for every 12 hours after the first 24 hours of transport.

The more intensive feeding of pigs for a few days prior to transportation is of no value and will neither increase the market weight nor reduce the shrink.

Floor space in rail cattle-wagons requires that cattle should be placed crosswise, alternately head to tail, in a fully loaded wagon. According to Zschokke (quoted by Edelmann [1]), adult bulls and steers require for this

purpose 66 cm and cows 57 cm of the wagon's length. The space he recommends for pigs is about 0.4 m^2 per animal, that for calves 0.31 m^2, and that for sheep 0.24 m^2. These figures should not be taken as a universal standard, since the size of animals of the same species may differ from country to country. Practical experience and local hygiene and welfare requirements should be taken as a guide.

The disadvantages and risks involved in rail transport of animals are determined by various conditions that need not be enumerated in detail. Experience has established that fat animals suffer more than lean ones. The greater the number of animals stowed in a wagon, the higher the temperature will rise and the greater will be the risk of suffocation. The longer the distance to be covered, the more exhausted the animals will become, with consequent greater loss of weight. The less suitable the wagons for the purpose, the greater will be the risks. It has further been established that pigs suffer more from transport by rail compared with other animals; this is undoubtedly due to their physique. Death from suffocation and heart paralysis is quite a common occurrence among pigs in transit. It appears that the constant swaying of the wagons causes the animals to fall down and they are then trampled upon by the others. This causes serious injuries, from which death will eventually ensue; suffocation may also occur.

Sea transport

For overseas transportation, Dutch shipbuilders have devised special vessels, the arrangement, equipment, and fitting-out of which are ingeniously adapted to the many needs that have become apparent during decades of animal transportation.

At first many transportation difficulties had to be solved, but these have all been satisfactorily overcome, and nowadays the loading and discharging are no longer problems, owing to specially constructed gangways, crates, and other contrivances. No difficulty is experienced in feeding and watering the animals on board ship, in contrast to the problems involved in doing so during road and rail transport.

In every country regulations have been drawn up governing the shipping of livestock. The requirements of the Foot-and-Mouth Disease Institute in Amsterdam, for example, are largely met through the shipping in of cattle, mostly from Ireland, that have never suffered from the disease. This subject has been studied from every angle, and questions relating to the required formalities, inspection prior to loading, attendants, rejection of unfit animals, killing instruments, construction of pens, ventilation, insulation, lighting and drainage, fire-protection, feeding, etc., have been considered.

A careful comparative study of the British, Canadian, Irish, and United States regulations on sea transportation of animals intended for human food shows that these are more or less identical with the laws in force in the Netherlands, which are reproduced in Annex 4, page 374.

Although not generally prohibited by regulation, ropes should never be used to tie cattle, either by the head or by the horns. It frequently happens that animals strangle themselves through falling and being choked. On the other hand, horses, being nervous animals, must be tied. Cattle will climb the gangway of a ship easily, provided its slope does not exceed 45 degrees; the gangways should not be slippery and should be provided with battens. They should also be just wide enough to allow the animals to pass, thus preventing them from turning round on encountering some obstacle. Feeding troughs are not necessary for cattle as they follow their natural inclination to eat straw direct from the ground or floor. Horses are often difficult to handle, especially the highly strung ones. It is helpful to blindfold them, especially during loading and unloading. Horses should be placed so that they will be supported on all sides; cattle, on the contrary, should have a little space in which to move freely. To guard horses against damage from their habit of head-tossing, roofing should be cushioned.

River transportation of livestock is generally not favoured, since it is too slow and cumbersome, and losses of weight are great even when feeding takes place *en route*.

Disinfection

The principal agents for disinfection of equipment, transport vehicles, and stockyards are:

(1) quicklime, freshly slaked;

(2) lime-water, in concentrations of 1/3 or 1/20;

(3) chloride of lime, $CaOCl_2$ (bleaching powder), to be used suspended in water in the same concentrations;

(4) concentrated chloride of lime, soluble in water and containing 70% active chlorine;

(5) chloramine T, $CH_3.C_6H_4.SO(ONa):NCl$ (sodium *p*-toluene sulfochloramide), containing 22% active chlorine;

(The two last-named chemicals should be used in concentrations of 2.5% or 7%. They are not suitable for the disinfection of manure.)

(6) a solution of cresol, $CH_3.O.C_6H_3(OH)CH_3$, stabilized by soap and marketed under the name of "Lysol", diluted with water to a concentration of 2.5%;

(7) a mixture of two parts of crude cresol and one part of sulfuric acid, diluted with water to a concentration of 3%;

(8) crude phenol, C_6H_5OH, diluted with water to a concentration of 3%;

(9) corrosive sublimate (mercuric chloride, $HgCl_2$) in an aqueous solution of 1% (as sublimate is very poisonous, it should be neutralized after 24 hours by a 0.5% solution of potassium sulfide, K_2S);

(10) formalin (CH_2O), in an aqueous solution of 1%;

(11) steam (particularly useful for the disinfection of blood and milk containers).

Two further means of disinfection which can be very effective are dry heat and burning.

Instruments, etc., may be disinfected by immersion in boiling water for 15 minutes (a 3% solution of washing soda (Na_2CO_3) or soap is useful for this purpose); hooks, handles, covers, etc., should be scrubbed in boiling water or soda solution.

The efficacy of a disinfectant depends upon the resistance of the contaminating agents, which can be divided into two groups:

(*a*) Those which are easily destroyed, together with those which do not leave the animal body. In these cases, a simple cleansing of walls, floors, doors, and tools with lime-water 1/20, or with a suspension of bleaching powder 1/20, suffices. For metal parts, an aqueous solution of cresol or phenol is preferable.

(*b*) Those which are not easily destroyed and which are communicable to other animals, as, for example, the agents responsible for:

anthrax
glanders
foot-and-mouth disease
blackleg
fowl cholera
pox
scabies
septicaemia
swine fever

In these cases, manure, straw, etc., must be burned, buried, or disinfected by storage for a long period and, in some cases, mixed with slaked lime.

Liquids such as blood and water should be disinfected with a 30% suspension of chloride of lime.

For walls, floors, instruments, etc., most of the above-mentioned disinfectants may be used. Metal tools or instruments should be sterilized by heat, if possible; otherwise, a solution of cresol or phenol is quite effective. This solution may also be used for wooden tools, rubber boots, etc. If these are of little value, they should be destroyed by burning.

Netherlands legislation lays down specific requirements for cleansing and disinfecting transportation facilities and equipment similar to those described above.

Conditions Induced in Animals by Transportation

In addition to the risk of injury, suffocation, and loss of weight already mentioned, attention should be drawn to some diseases that frequently occur in the course of transportation, or are directly caused by or related to it. These diseases include, among others, shipping fever, muscle bleeding, and transport sickness.

Shipping fever is a disease entity, associated with the shipment of livestock, of which the etiology has not been clearly defined. The *Pasteurella* organism is believed to be associated with it, and the prophylactic and therapeutic measures most commonly used are based upon this belief. Various vaccines, sera, sulfa-drugs, and antibiotics have been used for the prevention and treatment of this disease complex, but consistent results have not been obtained.[2]

The etiology of muscle bleeding frequently encountered in pigs has been ascribed to the lack of rest between transport and slaughter. Suffocation and damage to the central nervous system have also been implicated as causes.[4]

Transport sickness seems to affect cattle particularly and strikes older animals in advanced pregnancy, or those which have just given birth. Sometimes fat, non-pregnant cows are affected. The animals usually become ill about 24 hours after having been unloaded, although some may be affected during transit. The symptomatology resembles milk fever, and treatment is similar to that for the latter.[5] The etiology of the disease is not clear and has been variously ascribed to starvation, overcrowding, and unhygienic conditions in general. A differential diagnosis would have to include other metabolic disturbances such as ketosis and milk fever.

Necessity for Rest before Slaughter

Animal dealers have always been well aware of the undesirability of slaughtering animals too soon after shipment. Butchers say it is essential to give the animals a period of rest, as the meat of tired animals is not satisfactory for canning, salting, or sausage-making. So much stress has been laid on this point that most countries have regulations stipulating a rest period for animals on entry to the slaughterhouse. The duration of the rest period naturally depends on the season of the year and the state

of fatigue of the animal. Investigations have shown that tired animals do not bleed as well as those that have had sufficient rest. Bongert & Ficker (quoted by Lebbin [4]) have also shown that where cattle, calves, and sheep are in a state of fatigue, organisms, especially *Escherichia coli*, are absorbed through the mucous membrane of the intestines into the blood circulation, kidneys, liver, and lymph-glands of the intestine. This process is facilitated by hunger, which weakens natural resistance. A live animal has sufficient resistance to combat such organisms but, upon slaughter, the body's resistance is eliminated with the result that the hitherto uncontaminated carcass harbours organisms liable to reduce the keeping quality of the meat. It must again be stressed, therefore, that slaughter should be prohibited until the animals have been rested and have entirely recovered from the effects of transportation.

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Part III

SLAUGHTER

HYGIENIC CONSTRUCTION AND TECHNICAL ORGANIZATION OF SLAUGHTERHOUSES *

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The fundamental principles of hygiene, as well as economic considerations, demand that the slaughtering of animals for human consumption be carried out in establishments specially constructed for the purpose and kept under constant sanitary control.

In most European countries, a system of public slaughterhouses was set up following the suppression of uncontrolled slaughtering about a hundred years ago. In general, these slaughterhouses belong to the municipalities, and are subject to supervision by the municipal sanitary authorities.

Over the last fifty years, the standard design for public slaughterhouses has seen little change, although, in Italy for example, the more recently constructed premises have incorporated mechanical improvements. In so far as methods of work are concerned, too, apart from a few industrial abattoirs attached to processing plants where slaughtering is organized in accordance with modern techniques in use in the USA, these have remained more or less static, taking little account of current technical progress in the more efficient and more hygienic handling of meat for human consumption.

Moreover, there is no doubt that the public slaughterhouse system is costly from the standpoint both of installation and of management. Hygienic conditions are ensured but the system in practice involves the loss of a substantial proportion of by-products of specific commercial value. Furthermore, almost everywhere in Europe, facilities for the transport of meat, whether by refrigerator vans, where these are available, or by rail cold-storage, are inadequate.

It is therefore hardly surprising that there is an increasing call for reform of slaughterhouses, with a view to bringing down production costs and improving meat quality.

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* Useful information on this subject will be found in the first report of the Joint FAO/WHO Expert Committee on Meat Hygiene (*Wld Hlth Org. techn. Rep. Ser.* 1955, No. 99).

Research and Experiment

This demand has led to direct research and experiment in the larger meat-producing countries for the purpose of discovering to what extent it is possible to introduce new methods of work in slaughterhouses.

In this connexion, attention should be drawn to the important investigations carried out on behalf of Australian and New Zealand exporters in their anxiety to compete against South American producers for the European markets. Research initiated at the beginning of the Second World War aimed, in the first place, at determining the origin and extent of contamination of meat in slaughterhouses. It was found that the chief causes of superficial contamination were:

(1)	dirt and skins of animals	(approximately 33%);
(2)	pollution in the abattoir atmosphere . .	(approximately 5%);
(3)	the visceral content—in normal conditions	(approximately 3%);
(4)	transport and storage	(50% or over);
(5)	halving, quartering, and packing of carcasses	(approximately 2%);
(6)	miscellaneous—utensils, personnel, etc. .	(approximately 3%).

It was also found that the use of sawdust for the cleaning of the premises was indisputably unhygienic.

These findings led to recommendations which were attended by successful results. Measures applied included preliminary washing of the live animals, rapid removal of skins from workrooms, thorough cleansing of premises, utensils, and transport installations, supervision of cleanliness of personnel, provision of adequate water-supplies (the average amount of water required per head of livestock is 1000-2000 litres), prohibition of the use of sawdust, etc. As a result of these precautions, the risk of contamination during the slaughtering phase was reduced by 80%.

Experience has shown, too, that the interval between the slaughtering of the animal and the introduction of the carcass, whole or halved, into the refrigeration chamber should be as short as possible; it should not exceed one hour if the development of micro-organisms is to be prevented and the meat maintained in a condition to facilitate cutting up and to avoid excessive loss of weight.

It is obvious that these recommendations could not be put into practice without the introduction of new methods of work. They call, too, for carefully chosen building-materials and for the proper use of refrigerating plant. Investigations are needed to determine whether the techniques used in the USA meet the needs of European production of meat for local consumption. In Great Britain it has been proposed, under the present

programme for slaughterhouse construction, to build an experimental slaughterhouse on modern lines to serve as a centre for research on mechanical equipment and organization. The slaughterhouse in question will be of medium capacity (120 cattle and 100 pigs daily) and will have all essential services, including premises for the sanitary department and the requisite facilities for personnel. The proposed layout of the premises is very compact and the building will have one floor only. Plans include interesting innovations—especially with regard to the flooring (see page 134) and the installation of the overhead rails.

In Dublin, a slaughterhouse has been built that embodies all the most recent improvements arising out of the new techniques. It is larger than the one mentioned above ; 400 cattle and 2000 sheep can be handled daily. Most of the meat produced is utilized by an adjoining preserved-meat factory. The killing areas for cattle and for sheep are entirely separate, and an interesting feature is the system of forced ventilation which renews the air up to 30 times per hour, thus ensuring complete elimination of bad odours from every part of the establishment.

General ideas regarding meat supplies need to be revised for two fundamental reasons. First, some 90% or more of cases of food poisoning caused by meat or meat products can be attributed to post-mortem operations and handling ; less than 10% are due to the presence of disease in the living animal. Secondly, a change in existing industrial and commercial methods would make it possible to obtain good-quality products at prices 20% below current market rates.

The matter is therefore of undeniable interest both from the economic and from the social standpoint.

Efficient methods have placed the meat industry in the USA second in importance to the motor industry ; application of similar methods should likewise prove advantageous for European countries. Before new techniques are generally adopted in Europe, however, they must be subjected to careful and critical analysis in the light of hygienic criteria, administrative custom, and traditional work methods. These are all important factors which cannot be left out of account.

Economic Criteria

Whereas in the USA there are no public slaughterhouses and meat production is essentially an industry (although subject to strict sanitary control by the Government), nearly all meat production and distribution in Europe is in the hands of the municipal slaughterhouse establishments or of small privately owned establishments. The municipal slaughterhouse undoubtedly has merits from the hygienic and social viewpoints—if only

for the regulation of prices and the prevention of cartels. Future studies and research ought therefore to aim at the improvement of these existing facilities through the application of new principles. For instance, the desirability of entrusting the management of slaughterhouse establishments to co-operatives or municipal groups might be explored. On the other hand, it may be asked whether administrative and technical control should be separated. Judging by a brief examination of the production cycles, this distinction appears desirable, since it would enable functions and responsibilities to be clearly defined.

The constant improvements in cold-storage technique—today in universal use—and the increasing success of refrigerator transport, have led to a gradual diminution in the practice of transferring live animals to the large consumption centres. All available statistics go to show that there is an increasing preference for transporting the carcasses. One result is the tendency to decentralize slaughtering and to set up slaughterhouses in the production areas. From the economic standpoint, this has a number of advantages. It permits continuity of operations at the production and sale levels, simplified and economical transport, and elimination of deterioration in the animals due to the effects of live transportation. From the point of view of hygiene, there is a lower transmission of epizootics. On the other hand, decentralization may limit the choice of the types of meat available at the consumption level and make utilization of certain by-products more difficult. These slight disadvantages, however, are easily overcome by judicious organization.

Finally, the development of the " dead " cycle at the expense of the " living " cycle calls for fairly extensive modifications in the layout of slaughterhouse premises. The previous practice of keeping surplus animals at hand with a view to maintaining a regular rate of production has now given way to the greater use of refrigeration facilities, where meat in excess of demand can be stored, thus ensuring adequate supplies of fresh, matured meat at all times.

This decentralization of slaughtering and the technical advances made in refrigeration transport have led to the development of rational methods for the constant refrigeration of meat at all stages of transportation between the production area and the point of distribution to the public. One such system is in regular operation between French Morocco and the storage and distribution centres in Paris, and it is this source of regular supplies that helps to keep Paris meat prices at a reasonably low level.

Another factor of economic importance concerns the increased use of by-products of meat production, the value of which is steadily rising with improvements in preservation processes. The chief commercial demand is for certain parts of the viscera that have a nutritive value and for organs

that can be used by the pharmaceutical industry in the manufacture of special organotherapeutic products. Obviously, the utilization of these by-products complicates the technical organization of the slaughterhouse, but the resultant improvement in economic output justifies special attention being paid to this matter in drawing up plans for new establishments.

Hygienic Criteria

In the newer type of slaughterhouse with the most modern technical arrangements, there is a cycle of successive operations. This cycle starts in the killing pens, after which the carcass passes along a continuous conveyor rail. The succeeding operations may be carried out according to two different systems (see Fig. 1) : in scheme A, the carcass moves along a conveyor chain from which branch off the secondary circuits for the by-products ; in scheme B, the chain is interrupted at the place where the principal operations are carried out, the circuit subsequently being resumed and subdividing in the normal way.

It is evident that the " B " circuit enables the veterinary inspectors to maintain more careful supervision, in view of the fact that the inspection covers all phases of the work. Above all, this system allows for immediate seizure and consignment to the condemned section of any infected carcass or offal. With the continuous chain (" A "), on the other hand, the carcasses are already dressed before inspection, which means that the sanitary inspectors have less material at their disposal on which to base judgement. Moreover, it renders co-ordination with the inspectors on the visceral circuit extremely difficult, since it is often very hard to identify the organs from a suspect carcass. The difficulty is infinitely harder in so far as the skin and blood are concerned. It is also manifestly impossible to prevent all contact with other meat and with the utensils in use. In any case, seizure causes interruption in the chain of operations and, hence, loss of time, and this is the chief disadvantage of the " A " layout.

Since surface area and space in workrooms have been reduced in the newer establishments, certain new measures are essential in order to ensure hygienic conditions. The chief of these is provision for the mechanical renewal of the atmosphere in the slaughterhouse. The Australian experiment mentioned earlier testified to the role played by polluted atmosphere in the contamination of meat. The installation of a proper ventilation system with air-ducting, and possibly air-conditioning, is therefore highly desirable. By constructing multiple-block establishments with natural roof-lighting, a considerable economy in installation and production costs would be possible, while at the same time the principles of hygiene would be respected.

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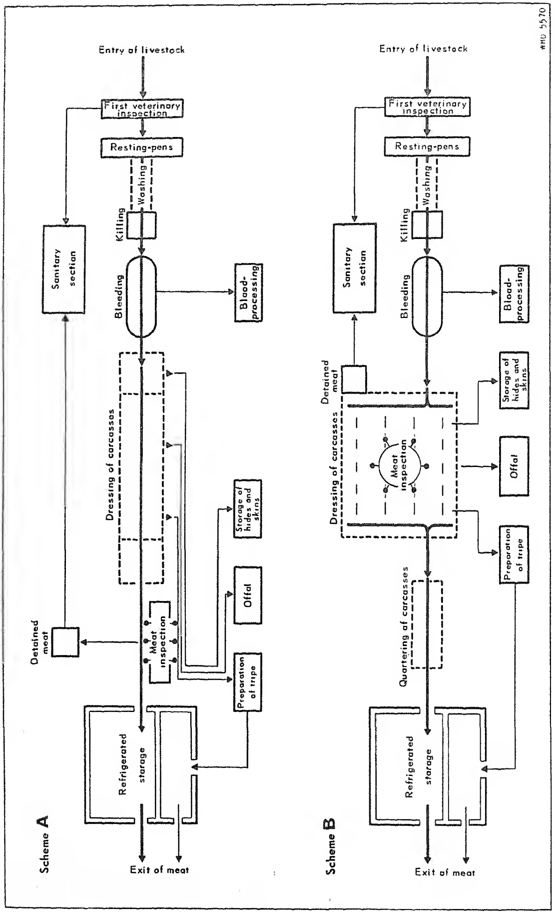
FIG. 1. ALTERNATIVE CYCLES OF OPERATIONS IN SLAUGHTERHOUSE



The new operational systems are based on the widespread use of up-to-date mechanical installations, which offer two advantages from the point of view of hygiene : first, a reduction of the time during which carcasses are exposed to the atmosphere and, secondly, a diminution in manual handling (see Fig. 2). On both these counts, electric quartering-appliances, circular and band saws for the halving and cutting-up of carcasses, and automatic classification and weighing appliances, merit unqualified approval. Such appliances should be periodically disinfected throughout the day, however, and treated with detergents at the end of each day's work.

Electric winches, placed at specific points in the work circuit, should take the place of the old hand models. The overhead single rail has become such an important feature of the circulation equipment that, in practice, it is part of the chain of operations. For this type of conveyor, the simplest and lightest appliances should be chosen, and the rail should be attached directly to the ceiling, to keep it free from dust and facilitate cleaning and disinfection, while not obstructing light.

It is essential that adequate space should be reserved for the ordinary installations (hot and cold water, steam, electricity, drainage of waste water, etc.), since their efficient functioning is indispensable for cleanliness and hygiene.

Another group of installations that should receive particular attention are those destined for the sanitary-inspection services. These essential services must be able to intervene rapidly in the principal circuit of slaughtering operations. It may be useful to recall briefly what functions the sanitary services are called upon to fulfil, since they are responsible for the maintenance of general hygiene, and the reputation of an establishment often depends on their effectiveness.

As a rule, sanitary inspection is carried out in two stages. The first is the examination of the live animals, which takes place at the time they enter the abattoir yard. Any animal which is considered unacceptable at the first examination must be immediately destroyed and rendered. Those regarded as suspect are conducted to the " quarantine " shed whence, after an adequate period of observation, they may be passed to :

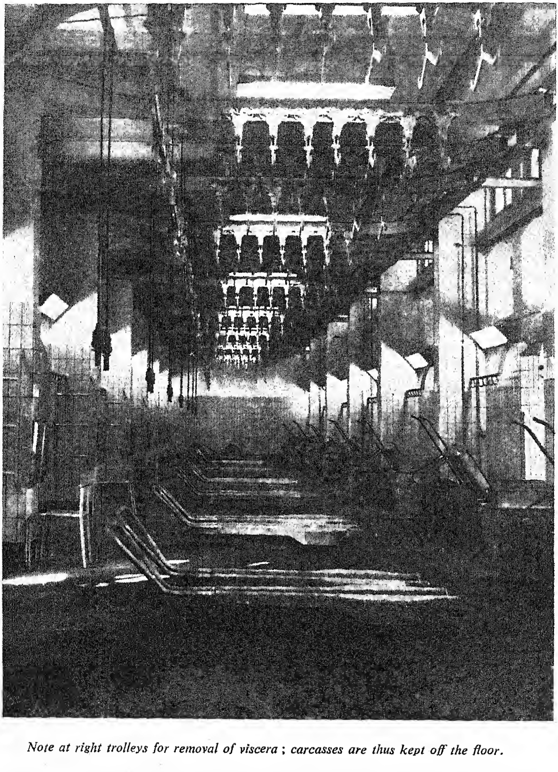
(*a*) the condemned slaughter room, for destruction and rendering, if found to be contaminated ;

(*b*) the " quarantine " slaughter room, if found partially usable ; or

(*c*) the normal circuit, if found to be sound.

The second stage is the inspection carried out during the operations that follow the actual slaughter. There are three or four separate items to be inspected and where a chain system of operations is in use in the abattoir these are effected at the specified points in the circuit for the principal

FIG. 2. OPEN-HALL SLAUGHTERHOUSE WITH TROLLEYS TO SUPPORT CARCASSES DURING DRESSING



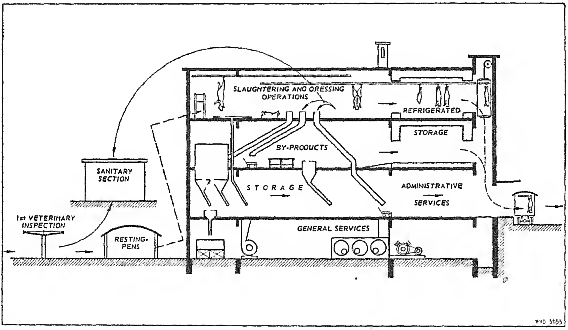
Note at right trolleys for removal of viscera ; carcasses are thus kept off the floor.

Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

operations. Inspection covers chiefly the head and abdominal cavity opening, the viscera, the halved carcass, and, finally, the dressed carcass. Whichever of the two chain systems is used, carcasses or parts of carcasses that are judged unacceptable must be taken out of the circuit immediately and removed to the appropriate section of the sanitary premises for destruction and rendering. Seized meat thus passes into the same circuit as condemned animals.

Consequently, in the newer establishments consisting of more than one storey (e.g., see Fig. 3), the sanitary premises should be located where they are accessible from all workrooms (cattle, small livestock, and pigs) without in any way interfering with the other circulation. This is not easy to achieve, and the problem can be solved only by a careful and thorough study of working conditions. The best course would seem to be to attach a detention room to each sector of operations and install lifts communicating directly with the sanitary premises. Lifts are the most practical means of transport since they enable the personnel to accompany the seized material and, furthermore, are easy to disinfect.

FIG. 3. FUNCTIONAL LAY-OUT OF MODERN TYPE OF SLAUGHTERHOUSE



The sanitary premises, divided into condemned and suspect sections, can as a rule be organized on normal slaughterhouse lines, since no important innovation has been introduced into their traditional functions. Incidentally, both sections should have self-locking devices fitted to the doors to prevent free passage of unauthorized personnel.

The plant for the destruction and rendering of unsound or dangerous meat should always be located in the condemned section, so there must be access to it from the suspect section. The latter is economically justifiable only when it has cold chambers and the equipment necessary for processing conditionally acceptable meat.

The veterinary inspector, by virtue of his position as the technical and sanitary director of the slaughterhouse, is responsible for control of the establishment at every stage of operations. Accordingly, any new construction on modern lines should include a special room for his use, from which he can exercise the maximum supervision and intervene as rapidly as possible when required.

Another problem is simplified under the new system of working in modern establishments—that of the hygiene and cleanliness of personnel. The additional premises for the use of personnel that are now considered indispensable for keeping contamination to a minimum and maintaining a healthier atmosphere should be placed in close proximity to the workrooms and should be well ventilated and lit.

Finally, there is the choice of construction materials and, in particular, of the materials to be used for floor- and wall-coverings. It is, of course, absolutely essential that walls and floors of workrooms, cold chambers, and other premises should be easy to wash, clean, and disinfect. Flooring made of a mixture of asphalt and hard core has apparently been judged satisfactory for the British experimental slaughterhouse mentioned earlier. Current experience in Italy seems to indicate that sandstone tiling—ridged to make it non-slip for flooring, and smooth for walls, troughs, and worktables—is excellent. These tiles are easy to clean and are resistant to wear and to the action of boiling water, detergents, and disinfectants. The relatively high initial cost is offset by the long life of the tiling, and it is therefore certainly to be recommended.

The question of the further installations and, in particular, of the circulation equipment is equally important. The importance of rapid removal of skins and other contaminating matter from the principal circuit as a prerequisite for safeguarding the hygienic condition and quality of the meat has already been demonstrated. Removal is generally effected through vertical shoots into a well or by means of sloping counters, leading to the respective departments on the lower floor. Sloping counters to take this detached material are definitely to be preferred, since they are easier to clean, either by sluicing or with detergents or disinfectants. Stainless steel is the most suitable material for this type of equipment, which has to be subjected to vigorous cleansing. Stainless steel should also be used for receptacles, such as trolleys, and boilers for cooking meat. The current

cost of stainless steel is reasonable, particularly when its durability is compared with that of other usable alloys.

Production Capacity: Technical and Economic Factors

In evaluating the advantages to be drawn from the new methods of organizing slaughterhouse operations, it must not be forgotten that the size of these modern, up-to-date establishments is determined by technical and economic factors together.

Hitherto, economics have not entered into the matter, since the ordinary municipal slaughterhouses are generally built to meet the needs of a particular community, the only limiting consideration on size being the need to make practical supervision possible. In practice, establishments are usually of a production capacity sufficient to supply a large town. Theoretically, there is no impediment to either a lower or a higher production capacity. In the USA, for instance, there are slaughterhouses with a throughput of 2000 cattle daily. But by excluding economic considerations, the slaughterhouse would be deprived of one of its chief functions in the social field, i.e., the production of good-quality meat at reasonable prices.

Accordingly, any new slaughterhouse project calls not only for a study of the initial costs of building and equipment, but also for a comparative study of production costs under the old and the new systems. Technical reports on the functioning of United States establishments provide data on the newer types, and from this it may be deduced that a regular throughput of 200 units a day (a unit being understood to be one head of heavy livestock, or three calves, or four pigs, or five sheep) is required to cover costs of operation; in other words, to operate without profit or loss. A higher rate of production would provide *pro rata* profits.

These facts make it possible to appreciate the full significance of the question. The logical conclusion is that the new systems of slaughterhouse organization can be applied only in very large establishments. On the basis of the annual per capita consumption in Italy, for instance, an establishment handling 200 units daily would cover the needs of about half a million of the population. It is therefore evident that the problem of the small or medium-capacity slaughterhouse cannot be solved except by the adoption of a combined system of refrigerator transport and storage or by continuing to build the existing standard type of abattoir. Whatever the course adopted, hygiene must not be the only consideration; economic aspects will certainly have to be taken into account as well.

Conclusions

It would seem that the question of general reform of meat-supply systems will need to be tackled at the national level. The problem is to co-ordinate regional plans, drawn up in the first instance on the basis of production and consumption statistics. These plans should be studied in the light of the respective advantages to be drawn from introducing the new methods of working in slaughterhouses and applying refrigeration techniques in the storage and transport of meat.

The primary aim is to offer the consumer the best-quality meat at prices below the current level. Since the data we now have on new schemes is encouraging, so far as production level is concerned, it would seem that the question as a whole merits fresh examination. Conflict is inevitable. It arises in connexion with any progress in the technical field. That should not, however, prevent us from facing the problem frankly, examining it thoroughly in all its ramifications, and endeavouring to solve it by the gradual and rational introduction of the new techniques.

METHODS OF STUNNING, SLAUGHTER, AND COLLECTION OF BLOOD

Dr T. BLOM

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Owing to the fairly general practice in some countries in Europe of running slaughterhouses as governmental, municipal, or co-operative undertakings, slaughtering has tended to become more and more concentrated in a relatively small number of slaughterhouses. This centralization has undoubtedly led to more rational and humane methods of slaughter as compared with earlier days, when animals were slaughtered in a primitive fashion either in the farmyard by the stockbreeder himself or else by the village butcher.

Centralization, however, has brought other problems in its train, and questions of hygiene have gradually come to assume a growing importance. This, in conjunction with greater awareness of the need for and value of more humane treatment and care of slaughter animals, has resulted in considerable progress in the technical field, as regards both animal transport and slaughterhouse equipment and installations. With the introduction of more modern techniques and working arrangements, hygienic conditions in slaughterhouses have greatly improved. Nevertheless, the vastly graver consequences of any slip in hygienic control in one of the larger abattoirs must not be overlooked. Its repercussions on public health would certainly be much more widespread than in the days of the smaller, home-killing establishments.

Slaughter implies putting an animal to death and subsequently preparing the carcass and organs for human food. Meat, in a broad sense, refers to all parts of the carcass that are fit for human food ; in its restricted sense, it includes the skeletal muscles and the accompanying body tissues (i.e., connective tissue, fat, tendon, bone, and blood-vessels).

So-called " emergency " slaughter is used for sick or injured animals. It is designed to save the meat for human food, wherever possible. Emergency slaughter should always be carried out in a special sanitary slaughter pen. In such cases, the meat should be subjected to bacteriological examination before final judgement is passed.

As a general rule, food control regulations prohibit the sale for human consumption of the carcass of an animal that has died from natural causes; in the case of an animal killed by accident, however, the carcass may be prepared in the ordinary way.

Experience has shown that blood is peculiarly open to contamination; hence, bacteria are more liable to penetrate and multiply rapidly in a tissue full of blood. Expert slaughter therefore aims at effecting as complete bleeding of the animal as possible, the obvious advantage being that this improves the keeping quality of the meat. The chief methods of slaughter in use are all directed to this end—to secure maximum bleeding of the animal.

Methods of Slaughter

The three chief methods are: (*a*) slaughtering without previous stunning; (*b*) puncturing the back of the neck prior to bleeding (pithing); (*c*) stunning prior to bleeding (see also pages 320-321).

Slaughter without previous stunning

This may be carried out by a stab in the chest or throat, or by cutting the animal's throat. Large blood-vessels in the anterior thorax may be severed by a stab and the animal bleeds to death relatively quickly, but bleeding from the throat is the most generally used method. After fettering the animal, the throat is cut so as to sever the carotid arteries and the throat veins. In so doing, the oesophagus is frequently damaged or even severed. Cutting the animal's throat is part of the so-called "ritual" slaughtering which has been practised for centuries by the Semitic people, among others.

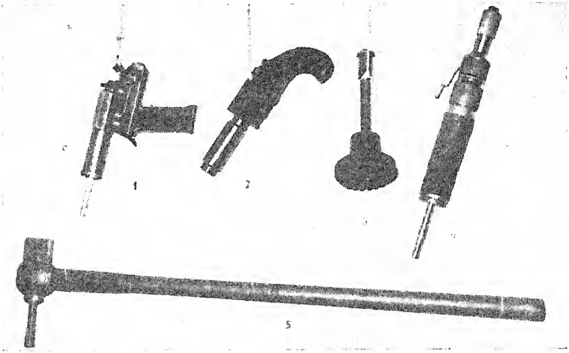
Puncture of the neck prior to bleeding

To puncture the neck, a knife is inserted between the first cervical vertebra and the occipital bone. The medulla oblongata is damaged and the animal at once collapses and remains motionless even during the subsequent bleeding. Breathing and heart action are greatly reduced, because the centre of these functions lies in the part of the central nervous system which is injured. There is no doubt that a well-performed neck puncture makes an animal insensible below the stab, but it does not appear to produce immediate unconsciousness. It has been maintained that consciousness would be dulled almost to unconsciousness through the effect of the shock, but this must be regarded as purely theoretical for the time being.

Stunning prior to bleeding

Immediately prior to bleeding, the animal is rendered unconscious by one or other of these means : a striking instrument, a pistol (with bolt or bullet), electricity, or gas (see Fig. 1). After the animal has been stunned, bleeding is carried out according to one of the methods described above. The most usual is by the stab in the chest.

FIG. 1. EXAMPLES OF STUNNING APPARATUS



1 = *captive-bolt type of pistol*
2 = *pistol delivering free bullet*
3 = *Staehl-Stoff apparatus*
4 = *Schermer pistol (another type of captive-bolt instrument)*
5 = *maul with sharp pin*

Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

A club or maul may be used as a striking instrument for stunning. The blow must be dealt with precision and force so that the roof of the skull is smashed at the outset, thus causing the animal to lose consciousness immediately. In cattle, the aiming point is the intersection of the lines drawn from the base of the horn on one side to the inner corner of the eye on the opposite side. At this point the brain is directly under the thinnest portion of the cranium, and the blow has the greatest effect. Lower down, the roof of the skull is double, because of the frontal sinus and the nasal cavity; higher up, closer to the base of the horn, the cranial bone becomes thicker. Horses have thinner skulls and are therefore easier to stun by a blow. In sheep and goats the brain is more readily reached

from the back of the neck. Pigs have a well-developed frontal cavity, which makes it difficult to affect the brain by a frontal blow, and in these animals the blow should be aimed one fingersbreadth above a line drawn between the animal's eyes. This method of stunning should not be used unless the head of the animal has been secured, as otherwise the risk of the blow missing the right spot, with consequent unnecessary suffering to the animal, is high. Use of the pole-axe also requires precision and force ; it should be aimed at the same spots as the maul. The pole-axe is an iron pick, generally fixed to a wooden handle. If properly applied, the axe is driven into the cerebrum and the animal loses consciousness ; it is not infrequent, however, for the blow to miss the right spot.

The slaughtering mask and the striking apparatus are improvements on the pole-axe. These instruments have a bolt that is driven into the animal's brain by a hammer-blow. For stunning pigs, in particular, there are a variety of different forms. The bolt usually has a spring action which returns it to its original position after the blow. Two people are needed to manipulate these instruments, one to hold the animal still and direct the blow and the other to use the hammer.

In some countries striking instruments have been replaced by pistols discharging a free bullet, of which there are a number of different kinds. Usually these are fired by a gentle blow with a hammer which projects the bullet into the brain. Such pistols should be handled with great care as accidents are not unknown, some due to misdirected shots and some to the bullet's having passed through the animal's head and ricocheted into the slaughter-hall.

To eliminate such risks, pistols have been designed where the bullet is replaced by a bolt which, after firing, is returned to its original position either by the exhaust-gas or by a spring. Firing is done by pressing the trigger with the same hand that holds and directs the instrument. In consequence, the pistol is easy to handle and very suitable for stunning shy animals, particularly horses. One disadvantage is that the bolt may get stuck in the fired position and become damaged before it can be freed from the animal.

In the last 20 years the stunning methods described above have been increasingly supplanted by electrical stunning,* particularly for pigs and small cattle. This is a method based on observations made in 1902 by the French physiologist, Leduc, who showed that it was possible to bring about complete narcosis in animals by leading a weak direct current through their bodies.** His experiments were not seriously taken up until 25 years later, first of all by the German, Müller.** Leduc's method was not directly

* For full discussion, see article by Croft, page 147.
** *Schweiz. Arch. Tierheilk.* 1950, **92**, 445

applicable to slaughter, where the purpose is to stun momentarily. For this reason, Müller used an overdose of alternating current together with direct current at a tension of 45-60 volts. The type of instrument at present in use looks like a pair of tongs. The electrodes are fastened to the jaws of the tongs and the leads for the current pass through the handles. The jaws are rifled or roughened to give a good hold when tightened. The electrodes are furnished with a sponge dipped in salt solution to enable the current to pass more easily through hair and hide. They are placed on the temples of the animal for the current to pass through the brain. As a rule, alternating current at 70-90 volts is used. To stun a calf 50-70 volts are sufficient; the amperage is generally 0.3-0.5. For the slaughter of pigs the circuit is closed for 10-20 seconds; for calves, about five seconds suffice. The longer time required for pigs is necessary on account of the greater resistance offered by the skull of the pig, and because preparations for pig slaughter take longer. If unconsciousness is not sufficiently deep, the pigs may recover before bleeding is completed. This method has also been tried for the stunning of cattle, but opinions differ widely regarding its suitability and nowhere has it been used on a large scale.

The moment the current passes through, the animal is seized with muscle spasms. These stop within 10-20 seconds and the head drops towards the floor; at the same time the legs execute reflex walking movements. If the animal is left undisturbed it regains consciousness in three to five minutes when it behaves as though nothing had happened. Electrical stunning thus produces mere lack of consciousness for a short period, whereas stunning by mechanical methods causes fatal injury to the animal. It is therefore important for bleeding to be carried out as soon as possible after electrical stunning. If the animal should regain consciousness during bleeding, this indicates that the method has not been properly applied, not that it is imperfect.

During the period 1930-40, there was a certain divergency of views regarding the efficacy of electrical stunning methods (see also page 254). Many people doubted whether the animals were really rendered unconscious and considered them merely to be paralysed, with awareness and perception of pain unimpaired. Others again were convinced of the excellence of the method and assumed that unconsciousness would ensue from anaemia of the brain. If that were the case, however, it would be too restricted to bring about complete anaesthesia. The interpretation generally accepted nowadays, based on experience gained in human medical research, is that complete unconsciousness is produced.

Stunning by electric shock is a method that has now been in use for a number of years, but a new type of apparatus has recently been perfected in the Netherlands. This again originated in human medicine, where electric

shock is utilized in the treatment of certain psychoses. For slaughtering purposes, a special apparatus has been devised, known as the "Elter-apparatus". This consists of stunning tongs similar to those used in ordinary electrical stunning, together with a device for adjustment of current to the watt-seconds desired, all built in to a special portable case and ready for connexion to the regular power-supply. The power per second required for successful stunning is estimated as follows: smaller animals, 198 watts; cattle (other than bulls) and horses, 285 watts; and, bulls, 420 watts. When the current is applied, the animal immediately loses consciousness and falls down with legs contracted and head bent forward. Nystagmus and cessation of breathing and of reflex action are observed, after which the legs are finally stretched out to the full. When the throat is cut, bleeding is effected very rapidly, helped by the return of breathing. All reports confirm that more complete bleeding is achieved by this method than after stunning by any other means. If left untouched, the animal will invariably regain consciousness and be quite normal again in some 10-15 minutes; no histopathological changes of the brain have been found.

Stunning by electric shock has a number of further advantages over other methods. First, the resultant state of unconsciousness is very deep; secondly, the strength and duration of the current may be adjusted exactly to suit the kind of animal; and, thirdly, complete unconsciousness is invariably produced. The captive-bolt pistol, for instance, does not always succeed in giving this third result; it may fail by reason of a very large or abnormally shaped head in the animal. Thus, from the standpoint of protecting the animal, the electrical method is infinitely to be preferred, and so far it has worked without a hitch wherever it is in use. By eliminating the pistol shot or blow on the head, it has greatly contributed to more humane practices in slaughtering and it is to be hoped that the method will become more widely used in the future.

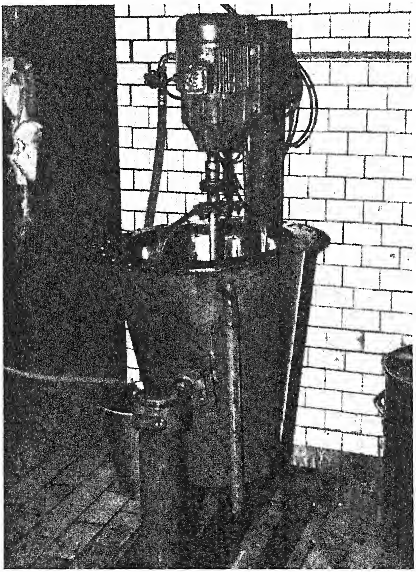
Incidentally, this type of stunning is very suited to ritual slaughtering. In 1952, the Royal Veterinary Board of Sweden prescribed its use for this purpose and the regulation was accepted by the Jewish churches in Sweden. Prior to 1952, gas was used.

The claim that in ritual slaughtering bleeding is more complete than in slaughter after stunning has, on closer investigation, proved to be incorrect. It is based on the paler meat derived from ritual-slaughtered animals. The reason for this lighter colour is that breathing continues longer in ritual slaughtering, which causes the blood to retain oxygen until the last possible moment. This in turn makes the blood paler and the lighter colour is imparted to the meat. Actual determination of the amount of residual blood has proved that the meat of ritual-slaughtered animals frequently contains more blood than the meat of animals slaughtered after stunning.

Collection of the Blood

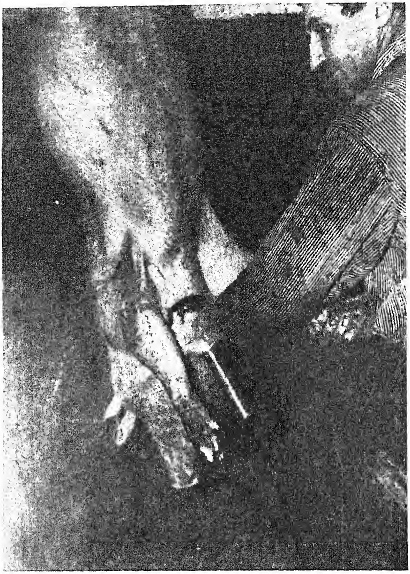
Where bleeding is effected by stabbing, the blood is allowed to drain freely from the wound and is collected and emptied into a vessel that is fitted with a stirring device to separate the fibrin and thus prevent coagulation (see Fig. 2). Coagulation may be prevented, too, by the addition of a special substance for this purpose. Many countries have already discontinued open collection of blood in this way, in order to eliminate the risk of contamination. An apparatus now in general use consists of the knife for

FIG. 2. DEFIBRINATION OF BLOOD BY A MECHANICAL APPARATUS : SWEDEN



Kindly provided by Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

FIG. 3. KNIFE WITH HOLLOW BLADE TO WHICH TUBE IS ATTACHED FOR HYGIENIC COLLECTION OF BLOOD: SWEDEN



Kindly provided by Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

making the incision, with a tube attached through which the blood drains away without coming into contact with the edges of the wound. Claims that the oesophagus is injured and the blood contaminated by this practice have proved to be incorrect. It is a method that is used particularly in pig slaughter.

It is possible to tap the blood through an entirely closed tube-system, and even to refrigerate it immediately. A special room, equipped for stunning and hoisting the animals, is generally used for this operation. The animal is stuck with a specially constructed knife, after which the blood is drawn off by means of a vacuum-pump or a milking-machine

pulsator, through a tube inserted in the knife (see Fig. 3). The blood is then mixed with a solution to prevent coagulation, and afterwards is allowed to run into the blood container. In this way, a perfectly clear blood-plasma is obtained for use in the preparation of various food products sold by pork-butchers. A special apparatus of this kind has been devised and is in use in Sweden.

This is a method that provides a product satisfying every reasonable hygienic demand. Bacteriological contamination is considerably greater in blood collected by the old open method. Stainless tin-plate containers, rather than wooden barrels that are difficult to keep clean, should be used for storing the blood under refrigeration.

Conclusions

A method of slaughter should be designed to permit as complete bleeding as possible without causing the animal unnecessary suffering. In practice, this means that bleeding must be preceded by stunning, and a number of countries already have legislation to this effect, notably Switzerland (which was the first European country to take such action) and Sweden. To obtain good bleeding, the heart and respiratory system must remain in action for as long as possible. Hence, neither a stab nor a blow in the back of the neck is an acceptable method of stunning, since injury to the medulla oblongata where these functions are centred invariably ensues. Shooting in the front of the cranium, followed by the insertion of a steel wire into the bullet hole, is no more suitable ; again, injury may be caused to the medulla oblongata and spinal cord. Accordingly, stunning by means of a captive-bolt pistol or by electricity is much to be preferred.

As the purpose of slaughter is to provide food for human consumption, thorough hygienic precautions in the slaughterhouse are essential. One important factor is that the water used should be of maximum purity. From the point of view of hygiene, slaughterhouse operations may be divided into two parts : the unclean process, which includes killing, bleeding, and skinning; and the cleaner operation of dressing the carcass (opening, removal of viscera, cutting up, and so on). The meat is more open to contamination in the early operations, as the animals are generally more or less soiled with manure and dirt when brought into the slaughterhouse. Furthermore, since the work is mainly manual, the possibility of contaminating the meat through handling operations is not inconsiderable. To reduce these risks to a minimum, therefore, it is essential that order and method should prevail in the slaughterhouse, and that staff should take every precaution as regards personal hygiene and clothing.

ELECTRICAL STUNNING

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In many countries the law requires that an animal shall be stunned before it is slaughtered for meat production, but the method of stunning is not specifically defined. The method used must satisfy a number of conditions apart from the primary one of producing unconsciousness. It must be easy to apply, and quick and reliable in producing its effect; since the object of slaughter is meat production, stunning must not produce any deleterious effect on the carcass or on its keeping properties (see also page 254); and finally, it must be carried out with a minimum of risk to the human operator.

Various mechanical methods have been used during the past 50 years, and recently a number of countries have adopted electrical methods for stunning both large and small animals. A variety of patterns of apparatus are in current use and their efficiency is mainly judged by practical results. This has led in some instances to false conclusions, because the assessment of unconsciousness in an animal is a difficult procedure; laboratory experiments have shown that an animal which appears to be unconscious may be merely paralysed and still conscious of pain.[6]

Theoretical Considerations

The physiological basis of consciousness is still in dispute, but recent research has shown that the state of consciousness of man and the higher animals can be determined by measuring the electrical activity of the brain. This pattern of activity changes as consciousness decreases in sleep or anaesthesia (see Fig. 1), and it is safe to assume that normal electrical conditions in the brain are one of the essential features of consciousness.[5, 6]

If electrical stunning is to be effective, the current must pass through the brain. This is easily arranged in man where the brain occupies a large

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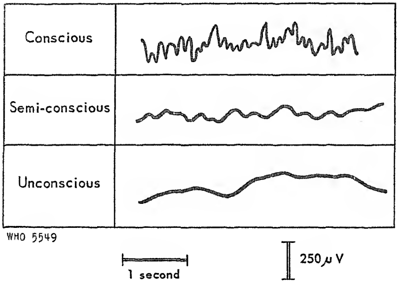
FIG. 1. ELECTRO-CORTICOGRAM OF RABBIT IN DIFFERENT STAGES OF CONSCIOUSNESS



proportion of the space within the skull, but in animals it involves accurate siting of electrodes since the brain is relatively small. Moreover, the irregularity of the external surface of the skull often makes it impossible to apply the electrodes at the ideal site. Current will take the shortest path between the two electrodes provided that the resistance of the various tissues in the region is approximately equal. Bone is a poor electrical conductor, so thickened areas of skull are unsuitable for the application of electrodes.

Early experiments were carried out with direct current, but it was soon realized that polarization effects made this type of current unsuitable. Alternating current is now generally used and eliminates polarization difficulties. The frequency of alternation is not critical, and experiments have shown that frequencies in the range 50-150 cycles/second are all equally effective. The common mains frequencies of 50 and 60 cycles/second are thus both satisfactory. Electrical stunning has the obvious advantage over the humane killer of silence, and since the voltage used is generally 70-90, there is little risk to the operator. There has been much discussion about the effect of this type of stunning on bleeding out and, in the case of pigs, on the formation of small haemorrhages in the tissues (" splash ").[1, 2] In the USA in particular it is held that the incidence of " splash " in pigs is increased by electrical stunning and that it is then difficult to distinguish " splashed " carcasses from those infected with hog cholera. Provided certain rules are observed, it is now generally accepted by English meat inspectors that electrically stunned animals bleed out as completely as any others, and that the procedure does not predispose to " splash".

Another important consideration is the position of electrical stunning with regard to Jewish ritual slaughter and the method followed in Mohammedan countries. Jewish law does not allow an animal to be "injured" before the throat-cut is administered, and until recent times this has meant that the animal is fully conscious when its throat is cut. Now, however, it has been decreed in Denmark, Norway, Sweden, and Switzerland that electrical stunning does not constitute an "injury"; hence it is permissible for an animal to be stunned in this way before it is dispatched by ritual means. In other countries this matter is still under consideration by the Jewish communities.

One of the problems connected with electrical stunning is the danger of curarization. If the electrical conditions are not correct, it is possible that an animal may be paralysed but not stunned. The animal cannot move or make any sound, so that the slaughterman naturally assumes it to be stunned.

Development of Methods

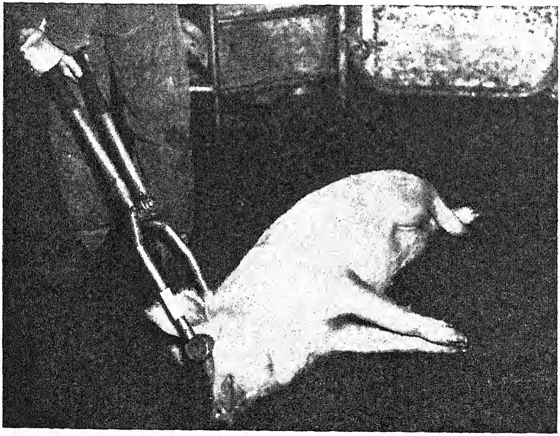
The phenomenon of electrical stunning was first described by the French physiologist, Leduc, who in 1902 gave detailed accounts of experiments on animals and on himself.[10] Little attention was given to the subject for the next 25 years, but from 1930 onwards numerous papers have appeared on the subject of electrical anaesthesia in animals and electro-convulsant therapy (ECT) in man.[3, 4, 10, 11, 12] Results have often seemed conflicting, but this is due partly to the variety of electrical conditions used, and, in the earlier experiments, to a failure to realise the significance of some of the variables.

Successful stunning depends on the passage through the brain of an adequate amount of electricity in a sufficiently short period of time. This, in turn, depends largely on the voltage applied and the resistance. In practice, the mains voltage is usually stepped down by a transformer to 70-90 volts. This reduction safeguards the operator against failures in insulation and reduces the risk of fractures in the animal; high voltages cause violent muscular contractions and increase the incidence of fractures. The greatest resistance is likely to occur at the junction of the electrode and the skin of the animal, and hence the surface of the electrode must be designed so as to penetrate hair and mud and make good contact with the skin (see Fig. 5, page 154). The operator must also realise that contact depends on the pressure with which the electrode is applied. Water or saline is often used to minimize the resistance at the electrode/skin junction; care must be taken, however, that this is not splashed carelessly over the animal's face so that it provides an alternative current path and short-circuits the brain.

The position of the electrodes is important, because the brain must lie between them if stunning is to be effective. Theories have been advanced in the past which suggested that cerebral anaemia could cause almost instantaneous unconsciousness. If this were true, electric current could be passed through the vasomotor centres in the lower part of the brain, or even through the heart itself, to produce unconsciousness. Recent work by Roberts [13] has shown conclusively that even when circulation of blood is stopped completely, consciousness persists for at least 12 seconds, and although this work was done on the dog, unpublished work by other scientists shows that similar results are found in the cow.

Electrical stunning has been used for many years in English bacon factories, and from time to time the problem of electrical curarization has been raised. This problem was initially based on human experience. Some people who have accidentally touched high tension cables have reported that they were unable to move or cry out, but were conscious of pain.[9] This condition was known as electrical curarization, and if it

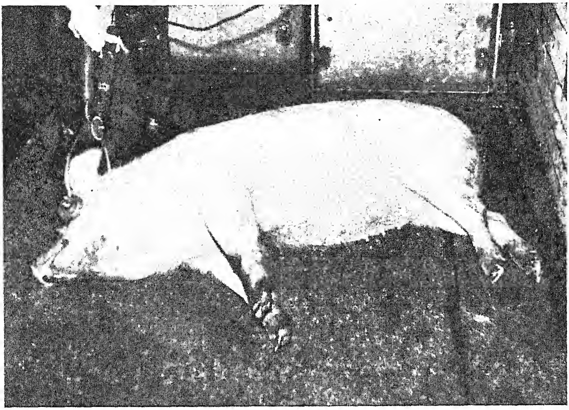
FIG. 2. ELECTRICAL STUNNING OF HOG: I



The animal is about to stretch its hind legs — an unmistakable sign that complete unconsciousness is setting in.

Kindly provided by Dr M. J. J. Houthuis, Director,
Municipal Slaughterhouse, Rotterdam, Netherlands

FIG. 3. ELECTRICAL STUNNING OF HOG : II



The limbs are rigidly extended and the head bent back, indicative that complete anaesthesia has been produced.

Kindly provided by Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

occurred in animals it would obviously not be recognized unless special methods were used.

Research on this problem was sponsored by the Universities Federation for Animal Welfare (UFAW) in 1948. The difficulty of assessing the state of consciousness of an animal was overcome by using electro-corticograms, and by noting the increase in heart rate following a painful stimulus, in a conscious animal. These methods, combined with data from human ECT research, enabled UFAW to reach certain conclusions.[6, 7, 11, 12] In particular, the behaviour of an animal which has been effectively stunned was described, and this is now generally known as an electroplectic fit. The fit varies somewhat in detail from one species to another owing to anatomical differences, but reports from independent workers in different countries show that a recognizable syndrome occurs in any animal. This syndrome can be divided into three stages :

(*a*) As soon as the current is switched on there is a violent contraction of all voluntary muscles and the animal falls over ; the limbs are rigid, and may be flexed or extended according to the relative strengths of flexor and extensor groups in the species (see Fig. 2, 3). Respiration is arrested.

(*b*) After about 10 seconds, assuming that the current has been switched off, the muscles relax and the animal lies on the ground in a flaccid condition.

(*c*) After a further 45-60 seconds, the animal starts to make vague walking movements with its legs, and respiration begins again.

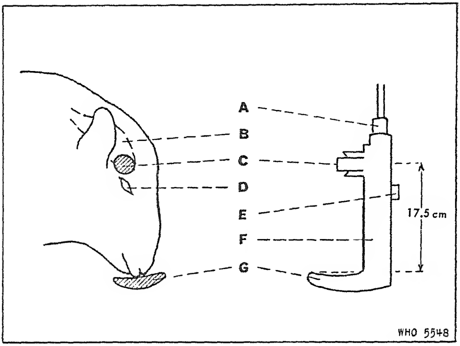
Observations on the pig show that it is completely unconscious for about 60 seconds after the application of an effective shock, and that it may then be curarized for the succeeding 30 seconds. After this it begins to get up and shows other signs of returning consciousness. Normally the pig is being bled out within 20 seconds of being stunned, so that the question of a period of curarization is irrelevant. If some hitch occurs in the production line there may be undue delay in stunning and sticking, and as a result bleeding may occur while the pig is conscious.

Practical Applications

The apparatus consists essentially of two electrodes connected to a source of power, and an insulated handle or pair of handles. The type most commonly used in England is similar to a large pair of tongs. The tips are modified to form metal cups with serrated edges and the cups are occupied by absorbent pads ; the handles are insulated and the whole apparatus is connected by a long flex to a source of alternating current with a voltage of between 70 and 90 volts. The electrodes are frequently immersed in a bucket of water so that the pads are wet, and the tongs are usually applied for a period of 2-10 seconds. This apparatus is widely used for pigs in bacon factories and in abattoirs, and is sometimes used for sheep and calves.

In some factories pigs are stunned with electrodes resembling wire brushes mounted on a sprung metal frame. This apparatus has a single handle and the frame is arranged so that the springs maintain good contact between the electrodes and the skin when it is pushed over the pig's head from behind. The electrical supply is the same as for the tongs-type of stunning apparatus. The current across the pig's brain when either of these instruments is used is about 0.2-0.3 amperes. Some abattoirs use a slightly different instrument for stunning sheep in which one electrode touches the sheep's nose and the other the side of the skull near the brain. This instrument is of a fixed size and is not, therefore, entirely suitable for animals in which the skull is much larger or smaller than the average. Also, the brain does not lie as completely in the path of the current, as it does when electrodes are applied on either side of the skull. The current across the sheep's brain when this instrument is used (see Fig. 4) is about 0.1-0.3 A.

FIG. 4. POSITION OF ELECTRODE ON SHEEP'S HEAD



A = *electric plug*
B = *brain*
C = *brain electrode*
D = *eye*
E = *switch*
F = *insulated handle*
G = *nose electrode*

Otsuki, in Japan, has recently developed an instrument for stunning animals electrically, and reports favourably on its use in abattoirs. It is essentially similar in principle to the apparatus previously described, but is used on a higher voltage. Cows are stunned with a voltage of 150-180, and pigs with 130-150 volts. The stunning current is given as 0.2-0.3 A, with a maximum of 0.5 A. This is very similar to that registered when the English type of tongs is used. Otsuki states that " splash " does not occur and that bleeding is good under these conditions.

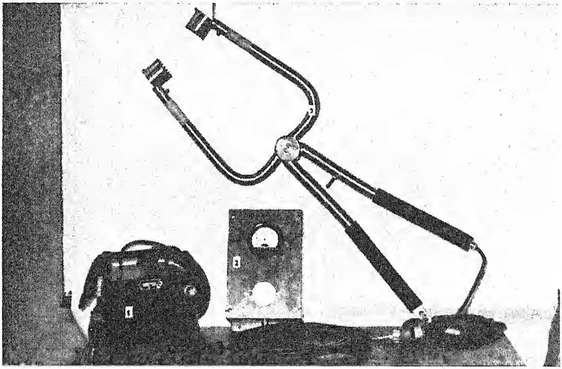
Recently, considerable attention has been focused on the Elther apparatus, designed and widely used in Holland.[8] The original form of the apparatus is similar in appearance to the tongs used for pigs in England, and is shown in Fig. 5 and 6. Modifications of the electrode handles have now been introduced for some models, as shown in Fig. 7-11.

The electrical set-up is similar in all these models but differs fundamentally from that used in English equipment. It is based on the findings of Barnhoorn & de Smet (1942).[3] These scientists were working on human ECT and concluded, as a result of their research, that the quantity of watt-seconds of electricity delivered to the brain was the critical factor in producing unconsciousness. The Elther instrument is therefore designed so that any given dose of watt-seconds can be delivered.[14]

Experiments have shown that bulls need 430 watt-seconds, cows and horses 285 watt-seconds, and smaller animals 198 watt-seconds. In all cases the tongs are applied for one second. If the same dose is given by using a lower voltage and longer time of application, occasional " splashed " carcasses occur and stunning may not be effective. This apparatus is very successful in practice, producing instantaneous unconsciousness for a long enough period to permit of slaughter, and causing no damage to the carcass. Bleeding out is rapid and complete because the heart continues to beat and a few respiratory movements occur. The method seems entirely suitable for stunning prior to kosher killing, and is in use in Sweden for this purpose.

If electrical stunning is to be a useful addition to the humane slaughter of animals for meat production, it is important to observe certain rules. There should be no delay between stunning and bleeding, since this increases the incidence of " splash " and allows the possible development

FIG. 5. ORIGINAL TYPE OF ELTHER APPARATUS *



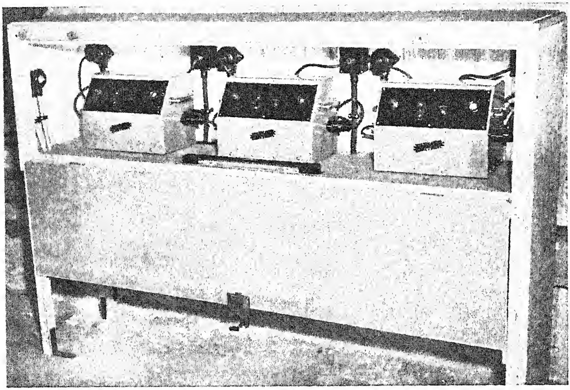
1 = *transformer (to transform mains current into 70 volts)*
2 = *ammeter (to measure current traversing brain ; needle should indicate 560 milli-amperes)*
3 = *tongs*

A scund signal on the circuit indicates that the correct dosage is being administered. Note serrations on electrodes which ensure good contact at electrode/skin junction.

Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

* Modified by Rotterdam Municipal Slaughterhouse and similar in pattern to English stunning tongs

FIG. 6. ELECTRICAL CONTROL CABINETS FOR THREE SETS OF ELTHER ELECTRODES



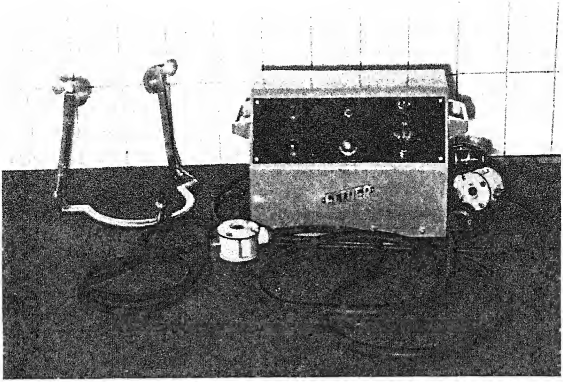
Storage box is slightly heated to prevent damp and cold.

Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

of a state of curarization. Secondly, the apparatus must be maintained in a good state of repair. Corrosion of electrodes is a common source of increased resistance and decreased current, and there are the usual dangers associated with frayed leads. Some factories use their own generator for electricity, but if the source of power is the mains, it may fluctuate considerably with the load carried. These variations will be transmitted to the supply to the tongs, and may then be responsible for a low stunning current. Finally, the operator may not apply the electrodes to the right part of the skull, or may fail to apply them firmly enough if they are of the tongs pattern.

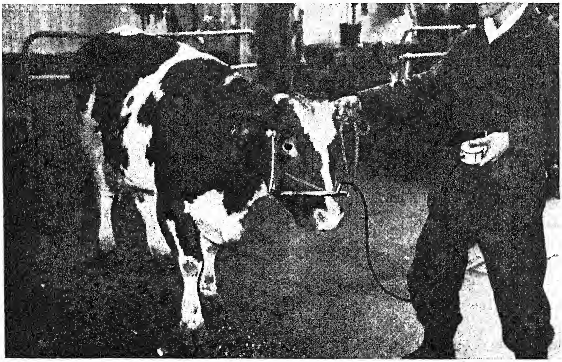
Unfortunately, in the English instrument there is no indicator to show whether or not adequate current is flowing across the brain. The time of application is also left to the judgement of the operator. The Elther apparatus has rectified these omissions, but in the majority of other instruments the behaviour of the animal is the only indication that the technique is faulty. An animal which has received an insufficient dose of electricity may be excited rather than stunned, and hence electrical failures can be dangerous as well as inhumane if the animal is used as an indicator.

FIG. 7. MODIFIED ELTHER APPARATUS FOR ELECTRICAL STUNNING



Kindly provided by Dr M. J. J. Houthuis, Director,
Municipal Slaughterhouse, Rotterdam, Netherlands

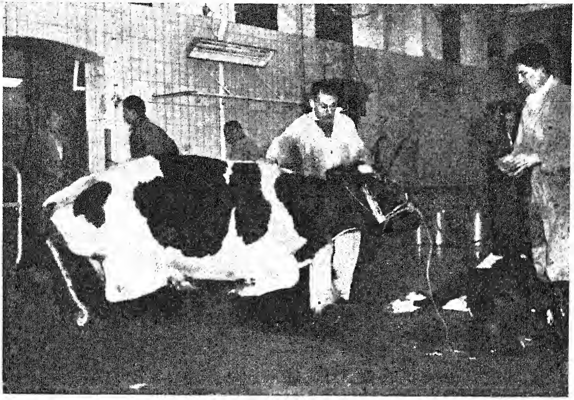
FIG. 8. MODIFIED ELTHER APPARATUS IN USE ON A COW: I



Note position of tongs, which do not inconvenience animal.

Kindly provided by Dr M. J. J. Houthuis, Director,
Municipal Slaughterhouse, Rotterdam, Netherlands

FIG. 9. MODIFIED ELTHER APPARATUS IN USE ON A COW : II



The button is pressed (right) and the animal falls unconscious.

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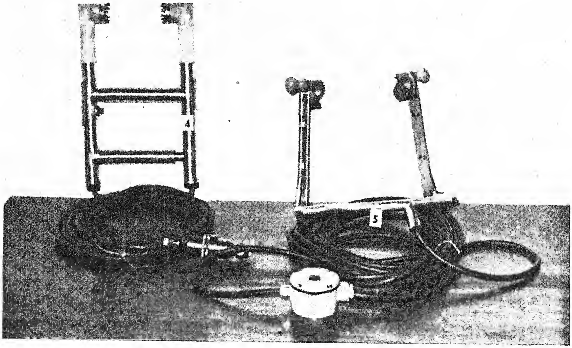
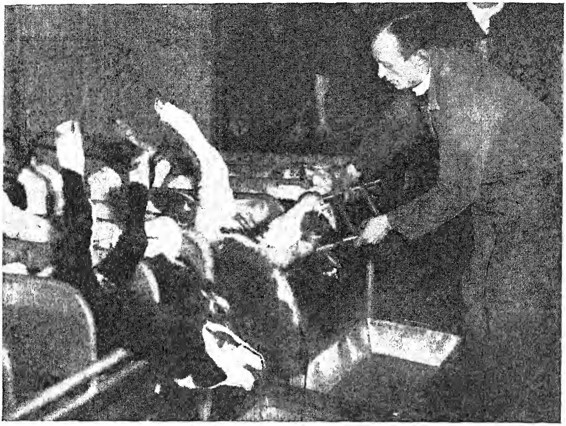
FIG. 10. ELTHER TELESCOPIC STUNNING TONGS



Left (4) = *for calves, sheep, and goats*
Right (5) = *for cattle*

Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

FIG. 11. ELTHER TELESCOPIC TONGS IN USE ON A CALF



Immediately after stunning, the carotid artery is severed and the animal is bled.

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Conclusions

Electrical stunning, if properly applied, is undoubtedly a useful method for the slaughter of animals for human food. It is quiet, compared with stunning by a captive-bolt pistol or humane killer, and obviates a fault of these instruments—namely, that the bolt may fail to penetrate the brain in the case of large bulls and boars.

The theoretical basis of this type of stunning has not been fully understood in the past and consequently progress has been made largely by trial and error. Now that ECT is the subject of extensive research in human medicine, and many scientists have studied electrical stunning in laboratory animals, it is possible to base practice on sound theoretical grounds. The remaining problems in this field, which include those of the occasional animal with unduly high electrical resistance, and of human error in siting the electrodes and in not applying them firmly, should be readily solved.

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THE MUNICIPAL ABATTOIR *

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Financing

In many countries the question of abattoirs is still regarded as a problem of secondary importance. Although almost all national legislations, including that of Switzerland, tolerate the existence of private slaughter-houses, in the author's opinion, it would be preferable for abattoirs to be publicly administered, with a budget independent of the national or municipal administration. Such a service should be autonomous from the financial point of view, neither the State nor the municipality profiting directly or indirectly from the receipt of taxes imposed on slaughtering and inspection, or from the rent of premises for the processing of by-products.

Tax revenue should be used exclusively to meet the cost of maintenance and operation, salaries and wages, including social insurance payments made on behalf of the personnel employed. In addition, taxes should cover normal interest on loans and the amortization of buildings and plant in 30 and 20 years respectively, these periods perhaps being shortened in agreement with the representatives of abattoir users.

As in private industry, any surplus profits could be channelled into a reserve fund — a prerequisite of efficient management — to be used eventually to cover costs of building and transformation, expenditure on the improvement and renewal of plant, as well as unforeseen budgetary items. In Switzerland, a well-managed public abattoir, with an average annual rate of slaughter of at least 8 million kg of meat taxed at the rate of 0.015% per kilogram, has a wide margin with which to meet running costs and interest on loans and amortization. General costs tend to diminish as slaughtering increases.

In every country, abattoirs and meat inspection (construction, plant, administration, operation) should be subject to legislation, requiring each township or group of townships to build official municipal abattoirs, where all the local slaughtering, with the possible exception of emergency cases,

* All illustrations refer to the Lausanne abattoirs.

would be performed under centralized supervision. This would undoubtedly constitute immense progress towards achieving a hygienic meat market and a step forward in the control of epizootics. In addition, the recovery of condemned meat—a vitally important question that is so often tackled in the wrong way— would be handled more efficiently.

The suppression of privately-owned slaughterhouses, as far as is feasible, would prove no great burden on the municipal budget, since public abattoirs—so long as they are well managed and their construction follows the normal pattern— are self-supporting, in that they provide the resources necessary for smooth running and repay the cost of building.

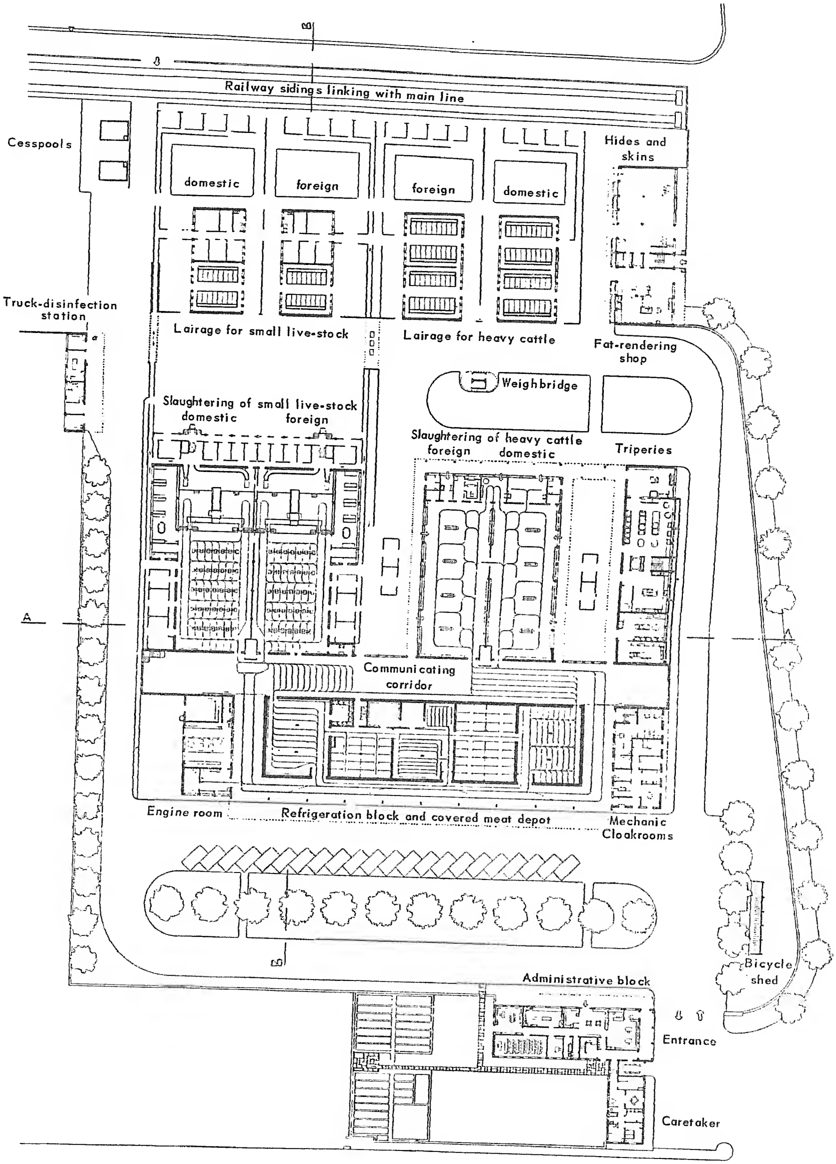
Nowadays, no one disputes the fact that the marketing and sale of meat require that animals be inspected before slaughter, that slaughtering be practised under hygienic conditions by fully qualified personnel, and that a meat hygiene service function in such a way as to satisfy consumers and at the same time safeguard public health and animal hygiene.

Needless to say, an abattoir may equally well be financed by private associations—co-operative or otherwise— under the administrative supervision of the public authority.

FIG. 1. GENERAL VIEW OF LAUSANNE ABATTOIRS, SOUTH-EAST ASPECT

The recovery plant is not visible, since it is situated in the north-west wing.

FIG. 2. GENERAL PLAN OF LAUSANNE ABATTOIRS



Organization

A modern abattoir is a factory in which cattle and other live-stock are slaughtered for conversion into meat. It must cease to be a mere agglomeration of primitive buildings and sheds, unhygienic both for the men who work in them and for the housing of animals and the preparation of carcasses.

The design of an abattoir is primarily a functional problem, of which the solution, so simple at first sight, is in fact extremely complex (Fig. 1, 2). There is no blueprint for a slaughterhouse, no prefabricated model. The design varies from country to country, with different usage and custom, and even from town to town, but as a guiding principle it should be borne in mind that every abattoir should render the greatest possible service at the lowest possible cost.

Although industrial-scale abattoirs are the easiest to run, the small enterprise cannot be suppressed with a stroke of the pen. The problem is much more complicated than many people believe, since in the countries of the western world economic and even political factors intervene.

Construction

Site

A modern abattoir, if properly conducted, reduces to a minimum any inconvenience caused by odour or noise to the residents of the immediate neighbourhood. The land, which should be as cheap as possible, should be sought in an industrial area near a town. The tendency to build only one abattoir for as large as possible a group of towns or villages (slaughtering centres) should be strongly encouraged, since this practice reduces operating costs. In European countries, where the cost of land is not prohibitive, public abattoirs should consist of one-storey buildings. Although, in certain circumstances, multi-storey constructions are to be recommended,* especially if available space is limited and the price of the land high, it should be pointed out that this type of building has its drawbacks. For example, frequent and costly maintenance is necessary to prevent the deterioration of ceilings through contact with waste products —blood, urine, acids, etc.

Abattoirs should be readily accessible both to users and to cattle, by road and by rail. The distance from workroom to butcher's establishment should be as short as possible; but thanks to the recent intensive development of motor transport this problem is no longer of primary importance.

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* See article by Scaccia Scarafoni, page 137, and Annex 6, page 383.

Furthermore, the management of the abattoir or the users' co-operative could very easily set up an independent transport system. Private railway-sidings are essential. From no matter what station the cattle are dispatched, they should be consigned direct to the abattoir station without trans-shipment. Any slaughterhouse situated near a river should be accessible by water as well as by road and rail.

Special attention should be paid to the facilities for waste-water disposal. From this point of view, the ideal site would be on a hill, near a watercourse or lake, into which it would be possible, after a simple purification procedure, to discharge wastes, such as the content of the animals' digestive tract, blood, etc.

Supplies of drinking water, which are indispensable, do not as a rule constitute a problem of any magnitude. It must always be borne in mind that abundant water is essential if the abattoir is to be kept impeccably clean. Water for washing should be recovered from the water used in the refrigeration process.

The proximity of a gas-works or other industrial undertaking able to supply thermal energy—waste heat, if possible—is always a favourable factor, since piped heating greatly facilitates operation.

Lay-out

The conditions under which the live-stock are housed, unloaded and driven, as well as the methods of slaughtering, should primarily be governed by the constant desire to spare the animals any suffering.

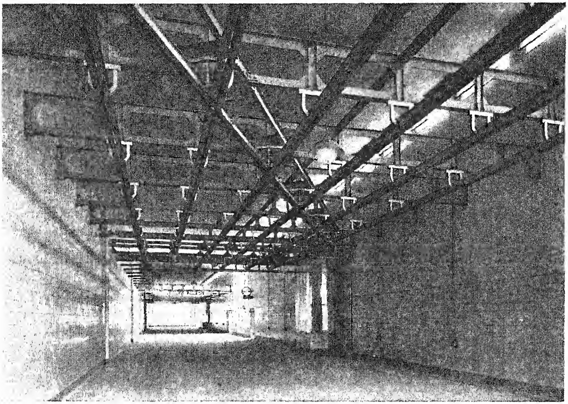
Bare brickwork is the most suitable—and the most agreeable—material for an abattoir. It calls for little maintenance and can be hosed down when necessary. Luxury should be dispensed with, the architecture being consistent with the requirements of a sober, simple factory, adapted to the nature of its work. Lairage, triperies and slaughtering halls ; cold-storage rooms ; engine rooms ; cloakrooms ; offices and analytical laboratories—each should be designed to suit the purpose for which it is intended. Lawns, trees and flowers would help to camouflage the matter-of-fact, utilitarian character of the buildings.

A hide and skin store and a fat-rendering shop should be situated in the immediate vicinity of the railway-siding, in order to facilitate the unloading of the hides and fats for processing, and their re-loading on to wagons. These installations should preferably form an integral part of the main building, even if they are operated by a users' co-operative or private company, so that the by-products may receive the appropriate handling and processing on site. The sanitary supervision of the hide and skin store and the fat-rendering shop should, however, be left in charge of the abattoir's veterinary service.

In the case of a large-scale slaughterhouse, the presence of subsidiary industries, such as curing, processing and canning, operated by private enterprise or by co-operatives, is to be recommended.

The slaughtering halls, triperies, gutteries, cold-storage rooms, engine room, cloakrooms, canteens, and service rooms of all kinds should constitute a single block in which each room opens on to a spacious, high-ceilinged main corridor (Fig. 3). This corridor links the slaughtering halls

FIG. 3. COVERED COMMUNICATING CORRIDOR

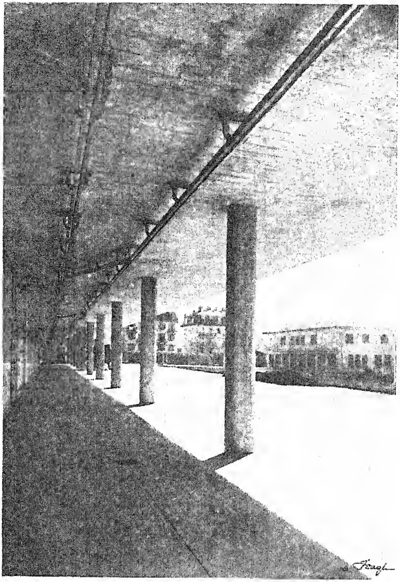


The corridor is powerfully ventilated and links slaughtering halls with refrigerating block.

with the cold-storage rooms, and also serves as an intermediate place of storage where the meat can drain off for two or three hours before being placed in the pre-cooling room at a temperature slightly higher than 0°C.

The meat should reach the pre-cooling room as quickly as possible. Despite the opinion of certain authors, this stage cannot be dispensed with, since it allows the meat to harden for at least 48 hours before cutting. Yet another advantage of the pre-cooling room is that it provides a link between external conditions and refrigeration. If, on the other hand, the meat is collected warm, it should be conveyed along covered passages to the meat depot, situated in front of the cold-storage room (Fig. 4).

FIG. 4. MEAT DEPOT



To the right: administrative block with laboratory for bacteriological and physico-chemical analysis.

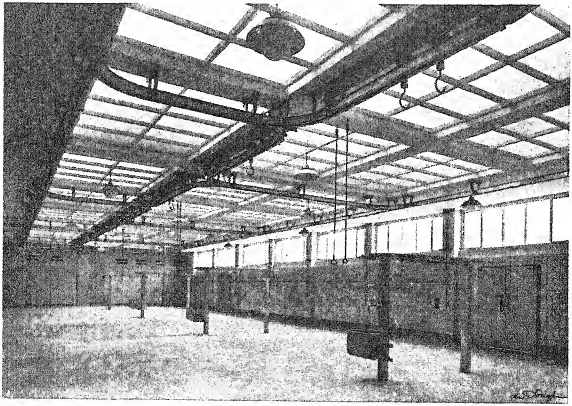
It is an error, both from the functional and from the hygienic point of view, to leave the space between the slaughtering halls and the cold-storage room completely exposed, with mere covered connecting passages, as is so often unfortunately the case, even in recently built abattoirs.

The communicating corridor should not, moreover, be used as the meat depot, as it is in the majority of European abattoirs, but should rather serve as the premises for a wholesale meat market. For this purpose, two stands should be established at either end, one for the sale of heavy cattle and the other for small stock. The slaughtering halls for horses and diseased live-stock should adjoin the abattoir block.

Each slaughtering hall (Fig. 5, 6) should preferably be divided into two halves by a single partition. Thus, if the amount of slaughtering slackens off, only one half-hall need be placed at the disposal of users. On the other hand, when the demand is heavy, gang-workers can be separated from slaughter-men working individually, an old-fashioned method which should not be prohibited in European countries, even in modern abattoirs. The dividing wall also obviates the risk of draughts, which would inevitably be produced in one large slaughtering hall in which the side doors remain open.

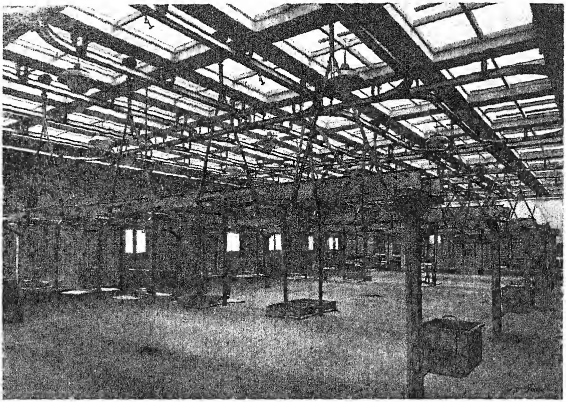
In the light of experience acquired at the Lausanne abattoirs, it should be emphasized that the admission of the animals from the side into the slaughtering hall is the only practicable means, in the case of heavy cattle, of avoiding contact between live-stock and carcasses. The slaughtering halls should also have a "clean" circuit and an "unclean" circuit, kept well apart from each other, with two separate systems of waste-water drainage, to prevent the "unclean" circuit water from polluting the meat depot. Where possible, a separate section for bleeding should be provided, in order to ensure that an inherently unclean operation be carried out in a place apart.

FIG. 5. SLAUGHTERING HALL FOR HEAVY CATTLE OF DOMESTIC ORIGIN



North lighting by overhead windows ; anti-skid floor ; air-conditioning ; hot and cold water.

FIG. 6. SLAUGHTERING HALL FOR PIGS, CALVES AND SHEEP



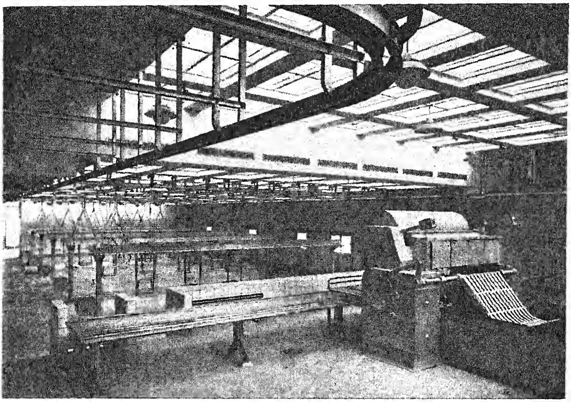
Benoit-type retractor for the slaughter of pigs, calves and sheep ; movable viscera-table ; air-conditioning ; hot and cold water.

The adoption of twin slaughtering halls, a system tried out for the first time at the Lausanne abattoirs, is fully justified by the results obtained. Moreover, this arrangement complies with the requirements of Swiss legislation aimed at combating epizootics, and also permits the simultaneous slaughter of foreign cattle, home-produced stock, and animals infected with foot-and-mouth disease, at the same time preventing all contact among these three groups. Until recently, this last requirement had been met either by slaughtering cattle of foreign origin in a special abattoir, or by refraining from the slaughter of domestic stock on the days when the imported animals arrived at the abattoir. The method of twin slaughtering halls allows the slaughterhouse to be divided into two completely isolated parts, as if it consisted of two separate establishments.

In large abattoirs, the triperies and gutteries should preferably be situated under the slaughtering halls and in direct contact with them, by means of a system of chutes. Thus, the triperies and gutteries dealing with large and small carcasses would be entirely apart. This system saves both time and material. The blood-processing section should be placed under, and in direct communication with, the bleeding-rails. Needless to say, these premises should be air-conditioned.

The triperies and gutteries should be mechanized to the greatest possible extent. Stainless steel and porcelain tiles are essential, and to attempt to do without them would not prove an economy from the point of view of operating costs. Excellent machines are now available for scalding and cleaning tripe, as well as for scraping intestines.

FIG. 7. SLAUGHTERING HALL FOR SMALL LIVE-STOCK



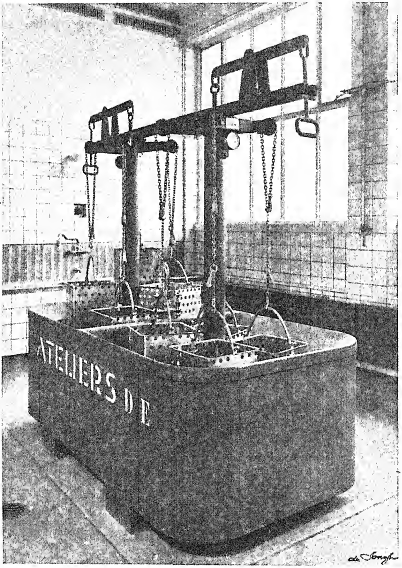
Shows dehairing floor (0.80 m above ground level) and cooling-off floor (at ground level). Dehairing machine seen from direction of vat. Conveyor rail with retractor-fixing device.

In the case of abattoirs serving towns of less than 300 000 inhabitants, where less than 50 000 pigs, calves and sheep are slaughtered annually, the author considers it advisable, in the interests of efficiency and economy, to slaughter all the small animals in common slaughtering halls, rather than to provide special sheds for the calves and sheep, or to slaughter them with the heavy cattle.

The pig-slaughtering hall (Fig. 7), where sloping floors are inexpedient, should have three different levels : (*a*) the killing floor, 1.60 m from the ground ; (*b*) the dehairing floor, with scalding vat (which, for reasons of hygiene, should be replaced by the modern system of steam dehairing and hosing) and singeing apparatus, 0.80 m from the ground ; (*c*) the cooling-off floor, at ground level. In this way, hoists are rendered unnecessary

and all operations can be carried out with the aid of chutes. The same principle applies to the processing of by-products, such as fats and greases, stomachs, tripe, etc. Pig-dehairing machines are indispensable in any modern slaughterhouse, as they ensure a speedy throughput. The pig guttery, as well as the vats for scalding the feet and heads of calves, should, if possible, adjoin the slaughtering halls (Fig. 8).

FIG. 8. VAT FOR SCALDING HEADS AND FEET OF CALVES



Stainless steel baskets ; thermostat ; heating by coiled piping in double partition ; double basins ; air-conditioning.

Traffic

An important problem to be solved is that of traffic. In principle, one gate only should serve both as entrance to and as exit from the grounds of the abattoir, in order to facilitate supervision. This sole main

entrance to the grounds should be barred by a double grille on rails, and its opening and shutting should be electrically controlled.

A so-called " unclean " circuit between animal pens and slaughtering halls is formed by the route of arrival of the animals driven by road. The stock are either housed in the lairage or brought to the unloading platforms outside the slaughtering halls, to be driven along narrow, guttered passages to the killing floors. A disinfecting station, with steam jets, should be provided for cleaning down trucks when these vehicles leave the terminal point of the " unclean " circuit.

The " clean " circuit should avoid all contact with the abattoir proper. From the entrance, it should skirt the covered meat depot, in front of the cold-storage rooms, and should leave again in the same direction. On no account should the meat depot be situated in the communicating corridor, as is the case in many abattoirs in Switzerland and elsewhere, for it is again emphasized that no vehicle of any kind should be allowed to run along the main corridor.

In addition to these two principal circuits, other circuits should be established in such a way as to avoid, on the one hand, any contact between " unclean " and " clean " operations, and on the other, any overlapping or backward movements. In brief, an effort should be made to ensure that the factory operates as efficiently as possible, while meeting all the requirements of modern hygiene and technology.

Architectural details and the subtleties of design will not be dealt with here ; for a discussion of these factors, the reader is referred to a booklet published on the occasion of the opening of the new abattoirs in Lausanne.*

Lighting

The illumination of the various abattoir departments is a question of fundamental importance. North lighting by overhead windows is preferable to side lighting. Direct sunlight should be avoided as far as possible (see Fig. 5, page 167). The plans should be drawn up in such a way as to allow the maximum amount of light to enter the premises and to be distributed evenly throughout the halls. In countries where there is a risk of freezing, the reinforced panes of the skylights should be insulated and heated.

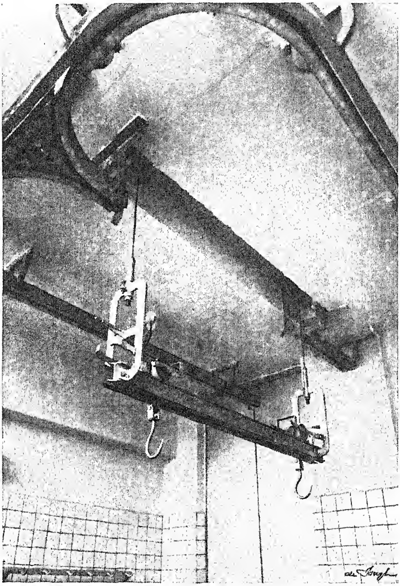
Overhead conveyor rail

The slaughtered animals should be transported in the simplest possible manner, by means of an overhead bi-rail conveyor system arranged in a

* *Les nouveaux abattoirs de Lausanne*, Imprimerie Vaudoise, Lausanne, 1945

vast closed circuit. This network should be kept at the same level throughout the abattoir. The by-products should be removed by special carts, or, better still, in the case of a larger establishment, by receptacles suspended from the overhead conveyor rail. The carts or receptacles should be adapted to the various operations.

FIG. 9. HOISTING BAR FOR TRIMMING HEAVY CARCASSES



Note simplicity of device ; direct linkage with conveyor system when hoisting bar is level with rail.

All the rail suspension components should be adjustable and fixed either to the reinforced concrete framework of the ceiling (see Fig. 5, page 167), or to steel girders, in the communicating corridor (see Fig. 3, page 165), or to the insulated ceilings of the pre-cooling rooms. Heat

galvanization of the entire system would prevent any possibility of rusting and dust collection. (It should be noted that in some abattoirs the overhead conveyor track is in the form of a monorail, flush with the ceiling.) The network should be provided with overhead balances for weighing the warm carcasses at the exits from the halls, and with lowering tackle in the pre-cooling rooms and meat depot. The hoisting bars or winches, forming a mobile part of the overhead conveyor network (Fig. 9), should be raised and lowered by a simple electric control. The electric hoisting winches, arranged in the roof-bays, are rendered invisible from below. In the event of protracted breakdowns in the supply of electric current, it should be possible to operate the hoisting gear by hand. This system facilitates trimming operations.

Thus, the travelling hooks suspended from the hoisting bar, which are used in the various operations, can also be employed in transporting the meat. In addition, the system permits of lower halls and rooms, which are easier to light and ventilate. The use of the hoisting bar does away with the need for superimposed rails and transport trolleys.

For pork, veal and mutton, a retractor suspended from the overhead rail is the ideal system. The author has in fact devised such a retractor (see Fig. 6, page 168), enabling pig carcasses to be suspended 2.05 m above the floor, and those of calves, 1.85. It is easily adjustable and can be fixed to slaughtering stands, thus forming bays with independent working stations.

Plant

Refrigeration, heating, ventilation

In addition to the actual slaughtering equipment, an abattoir must possess a refrigerating plant and a heating and ventilating system.

The cold-storage rooms, which are essential in any modern slaughterhouse, should be as spacious as possible. Abattoirs equipped with commodious refrigerating chambers and extensive lairage will not require enlargement as urban demand increases. The output of the various production departments is generally limited by the inadequate capacity of the animal stalls and cold-rooms.

Abattoirs consume a considerable amount of thermal energy, not only in heating their vast premises, but also in de-misting, scalding carcasses, boiling tripe, and cleaning rooms, trucks and railway wagons, as well as in providing showers and baths. Workrooms must be well heated, firstly to prevent freezing, where this risk exists, and secondly to guarantee working conditions equivalent to those of other industries.

Builders should pay particular attention to de-misting ; excellent systems for the elimination of steam and moisture are now in existence.

From the economic point of view, it would be advisable to install two separate systems for the superheated and hot water-supplies.

*Waste-product recovery**

An abattoir should also include a plant for the recovery of waste products, either small or on a more ambitious scale depending upon the size of the establishment. In point of fact, all the organic waste—accumulated in greater quantities than is generally believed—as well as the blood not recovered by the users of the abattoir, should be regularly converted into fodder for pigs and poultry. This will help to maintain that state of cleanliness which should always prevail in any modern slaughterhouse.

The recovery process should be as uncomplicated as possible. Nowadays, simple apparatus of variable capacity is available, in which organic matter of every kind can be converted into sterile meal after 3½ hours' treatment.

For the rendering of edible fats, the vacuum process is the only method worthy of consideration at the present time. It combines a maximum extraction rate with the minimum of handling and expenditure.

Waste-water disposal

The drains to be used for the discharge of water containing blood or acids should be made of earthenware, while those for the collection of rainwater only should be of ordinary cement. Spy-holes, siphons, vent pipes, etc., are essential to facilitate inspection and to prevent the escape of disagreeable odours. The pipes should be wide in diameter and steeply inclined, for it must be remembered that the waste water of an abattoir contains organic matter, such as hair, blood, fat, intestines, excrement, semi-digested mucilaginous food, etc., which easily clogs the drains. In Switzerland, there is excellent equipment available for drain maintenance.

All polluted water should be channelled into an extensive system of cesspools, for the collection of waste matter escaping through the floor gratings. The waste water should be purified by the simplest possible method (digestion of the organic wastes by heating; disinfection and deodorization with chlorine and ozone).

General Remarks

Various equipment

In order to save labour, all machinery should be self-starting and protected against breakdown by numerous devices. Air-conditioning is

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* See article by Albertsen, page 263.

essential in the cold-rooms. The water used for cooling the ammonia can be recovered in a tank, for subsequent use in cleaning operations.

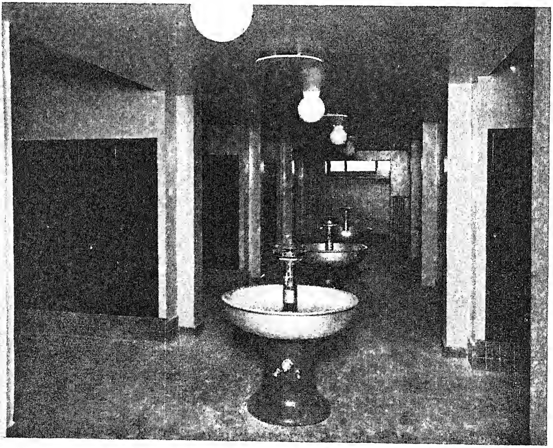
Pipes for drinking water, waste water, and hot and superheated water, as well as telephone cables and gas and electricity mains, should be situated in a chamber excavated under the entire length and breadth of the slaughter-house. All piping should be clear of the ground and readily accessible to maintenance personnel, so that it can be inspected at frequent intervals without the need for costly excavation.

All operations connected with meat inspection should be performed in a large laboratory situated in the administrative block next to the accounts department and control office (see Fig. 4, page 166). It is of the greatest importance that bacteriological, parasitological, physical and chemical analysis be carried out on the abattoir premises.

The floors of the various workrooms and even of the yards should be made of special, resistant concrete. While having a level surface, they should be rough and easy to clean. Porcelain tiles are advocated for the slaughtering halls, triperies, gutteries and fat-rendering rooms.

All doors should be shock-resistant but light in weight, hard-wearing and as noiseless as possible.

FIG. 10. CLOAKROOM FOR PERSONNEL



In the interests of surveillance, an observation post with the greatest possible range of vision is essential at the exit from every slaughtering hall.

Commodious cloakroom and canteen facilities should be provided for the benefit of the users of the establishment (Fig. 10).

Accurate weighing by automatic balances should not be dependent on the operator's reading powers ; the weight as indicated by the needle should be recorded automatically on a check card, with as many as three or four copies.

A visual call-system should be introduced, whereby the personnel and users of the abattoir can easily be contacted by telephone.

The director, the caretaker and a mechanic should live on the premises. The presence of a mechanic for the constant supervision of refrigerating and heating plant is indispensable.

Perhaps it is needless to stress the fact that an abattoir must be enclosed by a steel fence two metres in height.

Finally, care must be taken to avoid over-administration. Management and users alike should have their own, well-defined sphere of responsibility.

Municipal authorities wishing to construct an abattoir might usefully bear in mind a comment of Mr E. Herriot, former President of the French National Assembly and Mayor of Lyons : " Mr Mayor, show me your abattoir and I shall tell you how you administer your town." In conclusion, let us remember the words of Beaumarchais : " *La difficulté ne fait qu'ajouter à la nécessité d'entreprendre*."

Part IV

POST-MORTEM INSPECTION

GENERAL PRINCIPLES FOR POST-MORTEM INSPECTION AND HYGIENIC JUDGEMENT OF MEAT

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It is unnecessary to stress the essential public-health need for a complete and orderly examination of the carcasses and organs of all animals slaughtered for human food. Though this axiom is accepted by all enlightened countries, the implementation of such a procedure must obviously be related to certain factors, which include : (*a*) the adequacy of the personnel engaged on such work ; (*b*) the facilities provided for adequate post-mortem examination ; and (*c*) whether recourse can be made to laboratory assistance of a bacteriological and biochemical nature.

Though the procedure on any post-mortem examination may require some modification in order to adapt it to local conditions, there are certain guiding principles which must be observed no matter what the country concerned. This study covers the practical aspects of post-mortem inspection and judgement only ; it does not deal specifically with the bacterial and parasitic conditions which may render meat unfit for food, nor does it indicate in detail the assistance which may be afforded to the inspector through tests of a laboratory nature.

Premises and Lighting for Inspection

In practically every case post-mortem inspection of animals slaughtered at an abattoir is conducted in the abattoir itself, in either the slaughter-hall, the cooling-hall, or, in the case of animals sent in for slaughter in emergency, a special post-mortem room provided for this purpose. The efficiency of any post-mortem examination is closely related to the lighting provided, and wherever practicable the examination should be conducted in daylight. This point cannot be stressed too strongly and is particularly important in cases where the animal is suspected of having been imperfectly bled or of having been suffering from icterus at the time of slaughter ; abattoir experience has repeatedly shown the difficulty of recognizing green tints in muscle, fat, or connective tissue under artificial light. In

abattoirs which are poorly provided with windows, and in the afternoons of the winter months, the post-mortem examination must necessarily be conducted in artificial light; in such cases electric-light bulbs emitting a white light should be installed. One of the most onerous and tiring duties of an inspector is the routine examination of the submaxillary lymph-nodes in the heads of pigs; lesions due to *Corynebacterium equi* or to the avian type of tubercle bacillus may easily be overlooked if such infections are in an early stage. In some cases the inspector uses a small head-lamp which throws a beam on the cut surface of the lymph-nodes, while another type of portable inspection lamp fits into the thorax of the animal and illuminates the cervical area.

Timing of Inspection

Where practicable the post-mortem examination should be conducted at the time the animal is being slaughtered and dressed, or as soon as possible after the dressing has been completed. Inspection at the time of slaughter is essential in abattoirs of the factory type, for here a system of gang slaughter is employed, the carcasses being moved methodically along an overhead rail and each operator performing his own specific task in the dressing operation. In some abattoirs in the USA there is a throughput of 600 pigs per hour, and the whole technique of the process makes it essential that the post-mortem examination should be conducted immediately after evisceration of each carcass. It is now recognized as advisable that carcasses or sides be removed to a chilling-room within one hour of the completion of dressing, and this again makes it essential for examination to take place immediately after evisceration. Another reason that makes it desirable for the inspector to be present at the actual time of slaughtering is that it enables him to detect abnormalities, which may easily be overlooked if the post-mortem examination is conducted some hours later. Thus, the odour of a uraemic carcass may be very obvious when the abdominal cavity is opened, but this soon passes off and after a time the inspector may detect no more than a slight odour of ammonia. Similarly, icteric carcasses may readily be detected if post-mortem examination is conducted immediately after slaughtering, but the abnormal coloration of the tissues gradually disappears, owing to the enzymatic action of the reducing substances normally present in muscular tissue. The presence of an inspector during the slaughtering and dressing has a further value in that it discourages undesirable practices in the dressing operation. Bacilli of the paratyphoid group have been recovered in many cases from the gall-bladders of clinically healthy cattle, and it is therefore essential that the gall-bladder, particularly in cattle, be removed carefully without allowing its contents to contaminate other tissues. Again, in the dressing of cow carcasses, an inspector should ensure that pus or other

objectionable matter from the udder does not contaminate the carcass. In fact, it is a moot point whether or not the udders of cows should be admissible for human food ; the tissue may contain virulent *Brucella*, tubercle bacilli, and occasionally *Salmonella*, where the slaughtered animal is affected with septicaemia.

Methods of Inspection

General aspects

Perhaps the most important requirement in the conduct of a post-mortem examination is that it should be carried out in a methodical manner, following a definite sequence. A memorandum, issued in December 1952 for England and Wales by the Ministry of Food,* on the general inspection of cattle, pigs, horses, sheep, and goats, states that : " Organs and viscera should be examined as they are removed from the carcass or as soon as possible thereafter ", and that :

" . . . every carcass should be examined for :

(*a*) state of nutrition ;
(*b*) evidence of bruising, haemorrhage or discoloration ;
(*c*) local or general oedema ;
(*d*) efficiency of bleeding ;
(*e*) swelling, deformities or other abnormalities of bones, joints or musculature ;
(*f*) age ;
(*g*) sex ; and
(*h*) abnormal odour."

The practical aspects of this general inspection may now be considered in greater detail.

(*a*) The experienced inspector needs no guidance as to the differentiation between physiological leanness and pathological emaciation, though in borderline cases laboratory assistance may be sought, based on the fact that in lean but healthy animals the percentage of water present in the muscles is not above 76.5 and the percentage of protein about 22. In such cases the water to protein ratio is less than four to one, whereas in extremely emaciated animals the percentage of water present in muscle is about 80, and the percentage of protein about 19, giving a water : protein ratio of over four to one.

(*b*) Evidence of traumatism is usually discernible on the surface of the dressed carcass, and in the case of a carcass severely affected it is advisable to cut it into joints as soon as possible after slaughter, otherwise serum may infiltrate down between the muscles and lower its marketability still further.

* Great Britain, Ministry of Food (1952) *Memorandum regarding the methods and criteria of meat inspection recommended by the Ministry of Food for adoption by local authorities*, London (Memo. 3/Meat)

(c) Oedema may be of a localized form, such as hydrothorax, ascites, or oedema of the brisket which occurs in traumatic reticulitis. Generalized oedema is, of course, the more serious from the point of view of judgement of the carcass, and devices of a muscle-compression type are used in some abattoirs to demonstrate the increased fluid content in the muscle of an oedematous carcass. Assistance may also be sought from another laboratory test, based on the fact that in healthy cattle the bone-marrow contains about 25% of water, while if anasarca is present the bone-marrow contains about 50%.

(d) The degree of bleeding of a carcass can be assessed satisfactorily in many cases, a useful guide being that the blood-vessels on the surface of the carcass are apparent, and in beef carcasses valuable help may be obtained from examination of the intercostal veins which run parallel and immediately posterior to each rib; these veins are always discernible in poorly bled or unbled carcasses. Another useful guide in inspection of carcasses of sheep is to examine the prescapular lymph-node, which in badly bled carcasses is often deeply congested.

Care must be taken not to confuse imperfect bleeding with a condition known as "black beef". In the latter condition the muscles of the recently slaughtered animal have a relatively dark appearance, which becomes at once apparent when the carcass is divided into joints. There is little evidence that this condition is due to imperfect bleeding; it appears rather to be associated with an insufficiency of glycogen in the muscles at the time the animal is slaughtered. "Black beef" has been produced experimentally through lowering of the muscle sugar-content by administration of massive doses of insulin, and a similar result could be obtained by driving an animal to the point of exhaustion immediately prior to slaughter.

A point of importance in connexion with slaughterhouse practice is that the blood of a slaughtered animal, if intended for edible purposes, should be kept separate from other blood and identifiable with the carcass until the post-mortem examination has been completed. This desirable practice is difficult to enforce in those cases where a number of animals are bled together while suspended from a bleeding-rail, though it is perfectly practicable if animals are bled while lying on the floor and their blood is caught in shallow blood-trays. Blood should be rejected as unfit for human consumption in those cases where the entire carcass and all the organs are condemned, where the carcass or organs are found to be affected with any infectious condition, or where the blood has been contaminated by stomach contents or other extraneous matter.

(e) Abnormalities of the skeleton, including the bones and joints, may not always be obvious, particularly in carcasses of calves, where the practice of inflation is permitted. In these animals, judgement is also rendered difficult by the practice of leaving the skin on; as the skin may harbour

virulent organisms of faecal origin, this is a practice that should be forbidden in order to avoid contamination of the flesh from this source.

(*f*) and (*g*) Knowledge of the age and of the sex of animals is important, chiefly for record purposes, in the case of carcasses about which an inquiry may subsequently arise ; it is also important in that, over a number of years, useful data are obtained as to the age-incidence and sex-incidence of certain diseases, particularly such affections as tuberculosis or *Cysticercus bovis*.

(*h*) Abnormal odours may be of such a degree as to render a carcass completely unsaleable. These odours may arise from : (1) the consumption of strong-smelling or strong-tasting substances, e.g., fish meal or cod-liver oil fed to pigs, or the administration of drugs immediately prior to slaughter ; (2) the sexual odour of male animals, particularly boars ; and (3) products of abnormal metabolism. The odour most likely to be present as a result of abnormal metabolism is that of acetone, especially in carcasses of bovine animals slaughtered while affected with fever or when near parturition. This odour, which is quite distinct, is most readily detected in the large connective-tissue sheaths, in the kidney fat, and in muscular tissue ; it may be so marked as to render the carcass unsaleable. A laboratory test can be of assistance here. Abnormal odours of the flesh are said to occur in cases of parasitism of calves and sheep, and particularly in *Ascaris suillae* infection of the pig, but experience has shown that such cases are extremely rare.

Cooling

After the general post-mortem examination it is advisable that the carcass hang for some hours, either in the open air of a cooling-room or in a pre-cooling chamber, before it is moved to the chilling-room. The economic purpose of this is to permit of the rapid dissipation of body heat and thus prevent deep-seated changes of a putrefactive nature. Detention of dressed carcasses for a period of 12-24 hours enables the inspector to decide whether a satisfactory degree of rigor mortis has occurred.

Detailed inspection

After general examination the carcass must be subjected to a detailed post-mortem examination. The detailed inspection recommended in England and Wales is as follows :

1. *Head*

(1) *Cattle :*

(*a*) The tongue should be loosened but not detached and the surface and substance inspected.

(*b*) The roof of the mouth should be inspected.

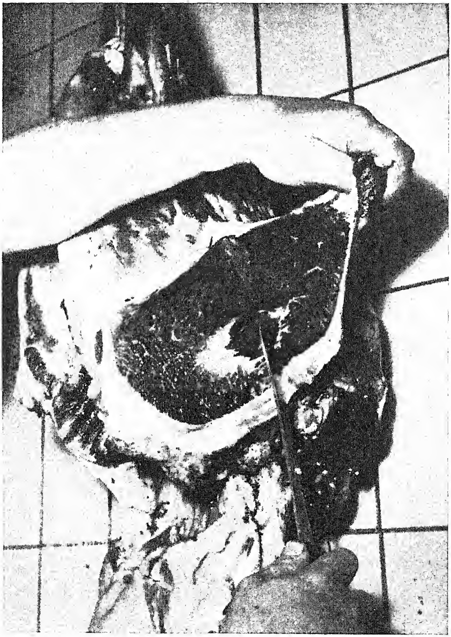
(c) The retropharyngeal, submaxillary, and parotid lymph-glands should be examined in detail.

(d) The cheek muscles should be examined by incisions parallel to the lower jaw (see Fig. 1).

(e) The eyes should be examined by observation.

(Note: In young or "bobby" calves, the above examination should be suitably modified.)

FIG. 1. EXTERNAL MASSETER MUSCLES OF OX BEING EXAMINED FOR PRESENCE OF CYSTICERCUS BOVIS



The examination should also include incision of the internal masseter muscles.

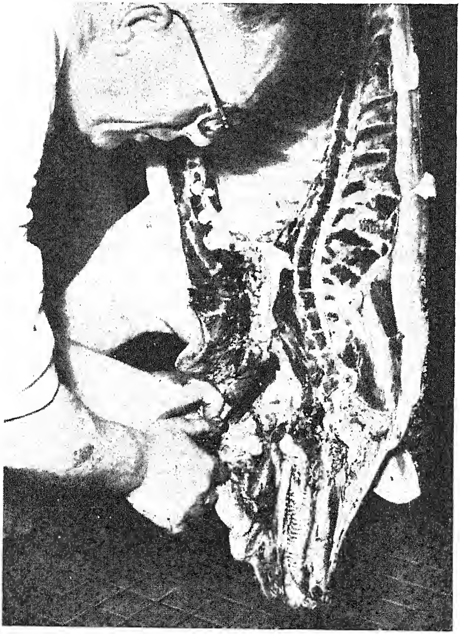
Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

(2) *Pigs :*

(*a*) The lips, gums, and tongue should be examined wherever practicable.

(*b*) The submaxillary lymph-glands should be examined in detail (see Fig. 2, 3).

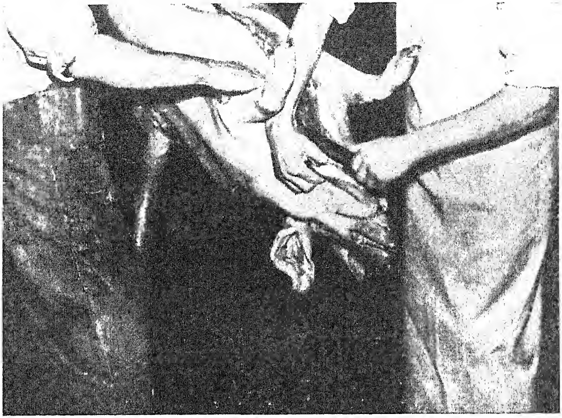
FIG. 2. THE USUAL METHOD OF EXAMINATION OF SUBMAXILLARY LYMPH-NODES



Contrast with Fig. 3, in which the inspector's work is facilitated by the use of a trestle.

Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

FIG. 3. METAL TRESTLE TO FACILITATE EXAMINATION OF SUBMAXILLARY LYMPH-NODES OF PIG: DENMARK



(3) *Horses :*

The head should be examined in the same manner as the head of a bovine animal, except that the cheek muscles of a horse need not be incised unless this is considered necessary.

(4) *Sheep and goats :*

The lips, gums, tongue, and nasal cavities should be examined wherever practicable.

2. *Abdominal cavity*

(1) *Stomach, intestines, and spleen :*

The outer and, when necessary, the inner surfaces of the stomach and intestines, the surface and substance of the spleen, and the surfaces of the omentum should be examined. The gastrosplenic and mesenteric glands of cattle, pigs, and horses should be examined in detail.

(2) *Liver :*

The surface and substance of the liver should be examined and the bile ducts incised when necessary. The thick end of cattle livers

should be incised. The hepatic lymph-glands of cattle, pigs, and horses should be examined in detail.

(3) *Kidneys :*

The renal lymph-glands and the adrenal glands should be examined and, when necessary, the kidneys should be exposed and incised.

(4) *Uterus and ovaries :*

The substance of the uterus, its outer surface and, if necessary, its inner surface should be examined; the substance of the ovaries should be examined.

3. *Thoracic cavity*

The pluck should be examined in the following manner before the organs are separated from each other:

(1) *Lungs :*

The lungs should be examined by observation and by palpation and, unless obviously diseased, they should be incised at the base. The bronchial and mediastinal lymph-glands of cattle, pigs, and horses, unless obviously diseased, should be examined in detail.

(2) *Heart :*

The pericardium should be opened and the heart examined and, if necessary, incised.

4. *Udder*

(1) *Cows and sows :*

The udder should be incised and examined by observation and palpation; the associated supramammary lymph-glands should be examined in detail.

(2) *Other female animals :*

The udder should be examined by observation and palpation; the supramammary lymph-glands should be examined in detail when necessary.

5. *Testicles and penis*

The outer surface and substance of the testicles and penis should be examined in detail. The superficial inguinal lymph-glands of the carcasses of bulls and boars should be examined in detail, but in other carcasses they should be examined in detail only if necessary.

6. *Feet*

The feet of all animals should be examined.

Following this section is a series of instructions outlining the "Additional Inspection that should be carried out where Evidence of Tuberculosis is found", and this in turn is followed by recommendations as to the "Action to be taken when Evidence of Disease is found". These recommendations are as follows:

The entire carcass, organs, and viscera should be rejected as unfit for human consumption if evidence of any of the following diseases or conditions is found (see also page 325):

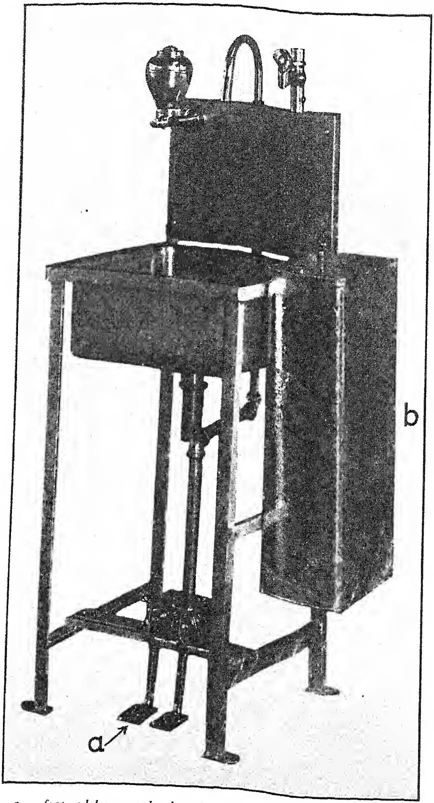
(1) Actinobacillosis, generalized, or actinomycosis, generalized
(2) Anaemia, advanced
(3) Anthrax
(4) Blackleg
(5) Bruising, extensive and severe
(6) *Cysticercus bovis*, generalized
(7) *Cysticercus cellulosae*
(8) *Cysticercus ovis*, generalized
(9) Decomposition, generalized
(10) Emaciation, pathological
(11) Fever (including salmonellosis)
(12) Foot-and-mouth disease
(13) Glanders
(14) Immaturity:
  (*a*) carcasses of stillborn or unborn animals
  (*b*) oedematous carcasses, and carcasses in poor physical condition
(15) Jaundice
(16) Malignant catarrhal fever
(17) Mastitis, acute septic
(18) Melanosis, generalized
(19) Metritis, acute septic
(20) Odour, abnormal, associated with disease or other conditions prejudicial to health
(21) Oedema, generalized
(22) Pericarditis, acute septic
(23) Peritonitis, acute, diffuse, septic
(24) Pleurisy, acute, diffuse, septic

(25) Pneumonia, acute septic
(26) Pyaemia, including "joint-ill"
(27) Sarcocysts, generalized
(28) Septicaemia or toxaemia
(29) Swine erysipelas, acute
(30) Swine fever
(31) Tetanus
(32) Trichinosis
(33) Tumours:
  (*a*) malignant with secondary growths
  (*b*) multiple
(34) Uraemia

In view of the fact that the incidence of specific infections in animals may, and does, vary widely between one country and another, it would be inadvisable to outline too dogmatically the detailed procedure as to how every carcass should be examined. Thus, in some countries, the high incidence of bovine tuberculosis makes it essential that an exhaustive search be made in every carcass for lesions of this disease. On the other hand, in some South American countries the incidence of bovine tuberculosis is low, whereas the incidence of parasitic infections, particularly *Cysticercus cellulosae*, is high, with the result that the predilection sites of this parasite in the carcass should be examined in every case. Generally speaking, carcasses of mutton require a less detailed and exhaustive inspection than do carcasses of beef, veal, and pork, one justification for this being that the sheep is rarely the animal furnishing the meat which serves as the vehicle of infection in food poisoning. Thus one would consider it unreasonable to require an inspector to examine in detail the lymph-nodes of the head, lungs, or mesentery of every sheep slaughtered, and it will be seen that the above instructions recognize that such a detailed examination is unnecessary in these animals. The practice of palpating the superficial lymph-nodes, either of the live animal or of the carcass, is carried out in some cases, but is of relatively little value.

A point that should never be lost sight of by the inspector is the necessity of avoiding mutilation of a carcass or organs to an extent calculated to lower their marketability or durability; many inspectors can recollect cases where the popliteal lymph-node of beef carcasses has been examined in summertime and putrefactive bacteria introduced on the knife, thus causing rapid decomposition in the muscles of the hind quarter. Such an occurrence can, of course, be avoided if the abattoir is provided with facilities for adequate cleansing of the inspector's and slaughterman's knives (see Fig. 4).

FIG. 4. LAVABO AND STERILIZER FOR CONTAMINATED EQUIPMENT



a = *foot-pedal operated valves delivering tempered water*
b = *sterilizer: water is kept boiling by injection of live steam*

Reproduced from A. R. Miller (1951) *Meat hygiene*, Philadelphia, by kind permission of the publishers

Emergency Slaughtering

The animal slaughtered in emergency presents the greatest problem to the meat inspector, and it is significant that in Australia no carcass of an emergency-slaughtered animal may be passed as fit for human food. In England praiseworthy recommendations have been made by the Ministry of Food in its memorandum referred to earlier, suggesting to local authorities that no undressed carcass should be admitted to a slaughterhouse unless it is accompanied by a certificate given by a veterinary surgeon, stating the reason for the slaughter of the animal and particulars of any drugs which, to his knowledge, have been administered to the animal and which might affect the carcass. In addition, it is recommended that no dressed carcass should be admitted to a slaughterhouse unless accompanied either by a veterinary certificate supplying the above information, or by a certificate of an authorized officer stating that the carcass and organs have been inspected and passed as fit for human consumption. Where it is necessary to slaughter an animal in emergency on a farm, the veterinary surgeon attending should be conversant with the necessity for complete disembowelling of the animal as rapidly as possible, and also for removing the lungs and heart from the thoracic cavity, leaving them still attached to the carcass, however, by means of the trachea. Particular attention should be paid in post-mortem examinations to the inspection of young calves for evidence of pyosepticaemia neonatorum, and any sign of enteritis with enlargement of the spleen and swelling of the lymph-nodes should excite the gravest suspicion. In Britain, *S. dublin* is the species of *Salmonella* most frequently associated with this condition, which is manifested by a blood-stained diarrhoea and pneumonia, and occurs most commonly in the warm months between May and October.

An accurate and scientific judgement of the meat of an emergency-slaughtered animal is well-nigh impossible unless facilities for laboratory examination are available. Without facilities for bacteriological and biochemical examination in an abattoir, it is inevitable that a very wide margin of safety must be extended to what are described as " borderline " cases of septicaemia, inasmuch as practical experience has repeatedly shown that the carcass of an animal slaughtered while ill may not reveal all the classical lesions of septicaemia on post-mortem examination and in some cases may exhibit little but imperfect bleeding and a moderate degree of icterus.

Routine Laboratory Examination

In some countries the meat-inspection regulations prescribe a list of diseases and affections in which a bacteriological examination is obligatory

by law. There is, however, a body of opinion which feels that the routine details as to the form the post-mortem examination should take, and also the affections in which a bacteriological examination should be undertaken, ought not to be made a legal duty of the inspector, and that a preferable procedure is to issue a list of affections in which a bacteriological examination is advisable, leaving it to the inspector's own judgement in deciding which carcasses should be subjected to tests of this nature.

Approval Procedures

In most countries a carcass which has been inspected and passed for food is stamped in several places on its surface. The stamp should include the date on which the post-mortem inspection was made and, if considered necessary, the initials or number of the inspector. The stamp indicates to the purchaser that the meat is regarded by a competent authority as fit for human food and, in some cases, stamps of a different shape are used for the various types of meat—e.g., beef, mutton, pork, and horse. Again, in some countries the stamping is extended to differentiate between animals of the same species, such as pork pigs and boars, a special " boar " stamp being applied to the carcasses of the latter animal to indicate that the flesh is unsuitable for ordinary cooking or frying but may be used for the manufacture of sausage. A stamp has a further value in that it is likely to discourage a butcher from accepting the meat of animals slaughtered illegally. It will therefore be obvious that the purchaser of meat which has been stamped is not only assured of its wholesomeness, but can also be certain that it is the meat of the animal that he has stipulated and not of any other and that it is not of inferior quality.

Every country has its own code of instructions on the action to be taken by inspectors to ensure that the public does not receive meat that is dangerous, innutritious, or unsaleable. These instructions, which are on broadly similar lines in the various countries, may be simply recommendations on action to be taken, or they may place a statutory obligation on the inspector to see that the instructions are fulfilled, but in every case the inspector is in a position to place the meat in one of two main categories at the conclusion of the post-mortem examination. Thus, he may release the carcass and organs unconditionally as fit for human consumption, or he may find the carcass and organs unfit and have them destroyed. Several European countries have adopted additional categories (see page 337), which recognize that meat may be (*a*) of a quality inferior to that which is normally accepted as sound meat, or (*b*) partially or slightly affected with a disease to an extent insufficient to justify condemnation, and hence could be reasonably sold, subject to adequate public-health

safeguards. The sale of meat coming within the first category is usually permitted at a reduced price ; in the case of the second, the sale—also at a reduced price—is either subject to adequate previous cooking of the meat or must be accompanied by explicit instructions to cook the meat before consuming it. These procedures are justifiable both on economic and on scientific grounds, and a great service could be rendered by encouraging their wider adoption throughout the world.

POST-MORTEM INSPECTION AND JUDGEMENT OF TUBERCULOUS CARCASSES

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It is now universally accepted that man and the different animal species can become infected with any one of the three types of tubercle bacillus.

In fact, much statistical material exists to prove that the bovine type of bacillus is responsible for certain forms of human tuberculosis, the proportion of such cases varying fairly widely from country to country (Görttler & Weber [21]). Verge,[50] in a general study on the danger from eggs, cites cases of human tuberculosis caused by the avian bacillus. Conversely, the human type of bacillus may infect animals, but whereas—as Verge [49] stressed—it appears to play an essential part in canine tuberculosis, pigs and cattle are less rarely affected than was formerly thought to be the case. Holth,[25, 26] Stein,[42] Plum,[39] van der Schaaf & van Zwieten,[41] Nielsen & Plum,[37] Hillermark,[24] Goret,[20] and, quite recently, Fromm & Wiesmann [17] have emphasized the part played by human beings suffering from open tuberculosis in the infection of herds under their control.

It follows from these findings that all animal sources of human infection are worthy of attention from physician and hygienist. Among them, foodstuffs should be the first to be suspected and this immediately brings up the question of danger arising from the meat of tuberculous animals.

It is a measure of the importance of this matter to recall that it has been one of the main concerns of numerous international congresses, both of veterinarians and of phthisiologists, ever since Chauveau [13] sounded the alarm in 1868 by announcing that he had succeeded in infecting three heifers by feeding them tuberculous material of bovine origin.

The changes in the scientific viewpoint on this matter that have taken place since that time can likewise be measured by comparing the opinion expressed by Bouley [7] in 1884 and by Arloing [1] in 1891 that all meat from tuberculous animals should be seized and destroyed, with that of Müller [32] (1933), who considered that the role of veterinary inspection should be restricted to the cutting-out of lesions. Midway between these two extremes, Cesari [11] in 1914 advised extensive sterilization of suspected

meat, stressing that the total seizure of carcasses was justifiable in a comparatively few cases only.

The decreasing severity of these views is reflected in the legislation of most countries, where regulations have become progressively more flexible and liberal each time a change has been deemed necessary.

In truth, there are two aspects to the tuberculous meat problem. One, purely medical, is concerned with protecting man and animals against any possible infection originating from meat. The other, which is economic and social in nature, condemns any waste of valuable animal protein at this time when the Food and Agriculture Organization is justifiably anxious about world food resources in face of the acceleration in world population increase. Now the quantity of meat lost to consumers throughout the world on account of tuberculosis is undoubtedly considerable. In the USA, a country where bovine tuberculosis has for all practical purposes ceased to be a menace to livestock, the following seizures on account of tuberculosis were made in 1953 :

	Adult cattle	*Calves*	*Sheep*	*Pigs*	*Horses*
Number of suspect animals	15 208 023	6 027 449	13 623 394	57 395 484	321 545
Total seizure	1 565	24	34	304 616	0
Partial seizure	0	0	0	0	0

In France, in 1953, for the area under the jurisdiction of the Veterinary Service of the Department of the Seine alone, 521 989 kg of meat and 289 000 kg of offal were withdrawn from consumption and destroyed on account of tuberculosis. In the face of such figures it is plain that everything should be done to restrict seizure to meat which is really harmful. Van Oijen [48] emphasized this point again quite recently when he wrote that the tendency in judging animals for slaughter should be, not to seize the maximum possible amount of meat, but rather to permit supply for consumption of the largest possible quantity consistent with a rational application of the law.

Scientific Basis for Seizure of Tuberculous Meat

On what scientific basis can legal provisions covering the judgement of tuberculous meat be founded ?

Strictly speaking, no muscular mass, no tissue otherwise suitable for use as food, should be supplied for consumption where it contains tubercle bacilli, no matter how few in number.

As a corollary to this proposition, the veterinary inspector should be able to assure himself, in deciding to release meat from tuberculous animals

for human consumption, that it is strictly incapable of causing infection. As Cesari[12] pointed out at the Zurich International Veterinary Congress in 1938, such a complete guarantee cannot be given on the basis of present technical possibilities. There is, in fact, no way compatible with the requirements both of meat inspection and of commercial presentation of making absolutely certain that masses of muscular tissue are completely free from tubercle bacilli.

Must this mean a return to the earlier extremely severe propositions of Bouley and Arloing? Certainly not, since these propositions were founded on the theory, nowadays recognized to be wrong, that the bacilli were constantly present in the blood of tuberculous subjects. It is now well established that tuberculosis is essentially an affection of the reticulo-histiocytic system (RHS), that the presence of the tubercle bacillus in the blood-stream is not constant and is in any case always ephemeral, and that muscle tissue is a poor culture medium for the mycobacterium.

These special characteristics of the disease therefore indicate that it is an exception for the tissues of a tuberculous animal, other than the constituent elements of the RHS, to be virulent and, even then, the degree of virulence is often low. Indeed, this has been confirmed (even though sometimes the techniques used may justifiably be criticized) by numerous experiments carried out to determine the virulence of the various non-lesioned tissues in tuberculous animals.

As regards muscle, a number of research workers (Nocard,[38] Chauveau & Arloing,[14] Galtier,[18] McFadyean,[29] Westerhoeffer,[51] Nieberle,[36] and Müller[33-35]) have obtained only negative or weakly positive results based entirely on guinea-pig inoculation which, according to Bretey,[9] is the most sensitive method since a single bacillus may sometimes suffice to develop tuberculosis in the guinea-pig. The liquid extract from the muscles of the tuberculous animals tested proved to be virulent in a few cases only and, even then, it did not cause tuberculosis in all of the guinea-pigs inoculated. It is only right, however, to cite, side by side with these, the more serious results obtained by Bongert[5] (11 out of 27 cattle tested) and by Raschdorff[40] (34 out of 50 cattle tested), although in these cases special pathological changes were involved which will be discussed later. Quite recently, however, van Oijen[48] tested muscle from 12 cattle affected with tuberculosis in different sites, several of the animals being in a poor condition, and he obtained negative results only.

At present the findings are sufficiently numerous to justify the conclusion that the infective power of the muscle tissue of tuberculous animals is extremely low, apart from certain types of lesion where virulence is more often found but is neither constant nor high. The infective power of muscle is so small that Müller[32] concluded that there was absolutely no

danger of infection via the digestive tract, introduction of the bacillus by this route being much less dangerous than by inoculation.* Compared with muscle, various types of parenchymatous tissue rich in RHS elements are notoriously more infectious. Müller[33-35] was able to detect bacilli in 55% of spleens, 50% of livers, 33% of kidneys, and 24% of udders from animals suffering from various forms of tuberculosis but apparently free from lesions. Numerous other authors have also been able to detect the tubercle bacillus in lymph-nodes of tuberculous animals, apparently perfectly normal (Cesari,[10] Vallée,[44] Swierstra,[43] Joest, Noack & Liebrecht,[27] Bongert,[5] Arloing,[2] Müller,[33-35] and Cormio[15]).

Thus, research has confirmed the theory that the tubercle bacillus once introduced into the animal body rapidly becomes localized in the RHS elements. This fact, moreover, is sufficiently proved by autopsy findings, which indicate the frequency of tuberculous lesions in the lymph-nodes and various lymphoid formations, the large serous membranes, the liver, the spleen, or the bone-marrow, as compared with the rarity of such lesions in the muscles, glandular parenchyma (salivary glands, pancreas, endocrine glands), the gonads, or the nerve centres. Finally, definite proof of the theory is supplied by the fact that Ghon's primary complex law and Parot-Cohnheim's law of parallel adenopathy are almost always confirmed.

Nevertheless, it cannot be denied that tubercle bacilli are sometimes found in the blood-stream of an infected animal. There are numerous reports of blood from tuberculous cattle giving rise to infection upon inoculation into the guinea-pig (Galtier,[19] Bang,[3] Bollinger,[4] Hagemann,[23] Bongert,[5] Müller,[33-35] etc.) or providing a positive culture on suitable media (Bang,[3] Eidherr,[15] van Oijen,[47] Meyn,[30] etc.). On the other hand, mention must also be made of the negative results obtained by other workers (McFadyean,[29] Nocard,[38] Raschdorff,[40] and, quite recently, Bouhier[6]). The contradictory nature of these results is sufficient indication of the fact that the presence of the tubercle bacillus in the blood is inconstant and that to speak of tuberculous bacillaemia would be a contradiction in terms, to use the expression employed by Cesari.[12] But it also indicates that the presence of the bacilli in the blood must correspond to certain special circumstances marking the long struggle between the attacking bacillus and the host.

Tuberculous Infection and Development of Tuberculosis

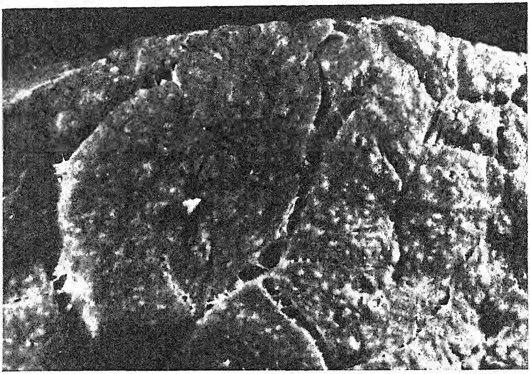
This is a matter already well on record. Nieberle,[36] in his report to the Zurich International Veterinary Congress in 1938, gave an excellent

* In contradistinction, see Meyn, A. & Schliesser, Th. (1954) *Mh. prakt. Tierheilk.* 6, 105.

description of how tuberculosis develops and, hence, a brief summary will suffice here.

There are four basic points of access for the bacillus: the lungs (air-borne infection), the pharynx (bucco-pharyngeal route), the intestines (digestive route), and the umbilical vein (the umbilical route of congenital tuberculosis). After penetrating into the animal body, the bacillus of the primary infection gives rise to a lesion at the point of penetration (Kuss's primary focus), followed rapidly by a lesion in the corresponding lymph-node, the whole representing the "complete primary complex". Frequently, the primary focus cicatrizes and only the lymphatic lesion persists; this is the "dissociated primary complex".

FIG. 1. MILIARY TUBERCULOSIS IN LUNG OF OX



Note also the presence of emphysema.

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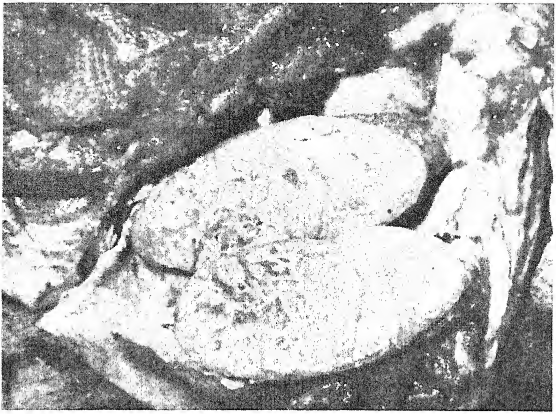
The process may remain limited to the primary complex throughout the life of the subject. On the other hand, in the case of a host that has not yet built up resistance against tuberculous infection, the bacilli may begin to multiply rapidly soon after the establishment of the primary focus and spread through the blood-stream, either directly, by breaking through

FIG. 2. TUBERCULOSIS OF SUBMAXILLARY LYMPH-NODE OF PIG CAUSED BY BOVINE TYPE OF BACILLUS



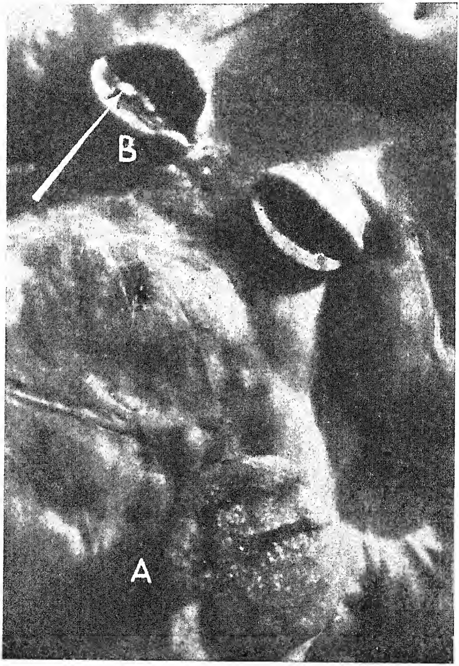
Kindly provided by Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

the wall of a vessel, or indirectly, by by-passing the intermediate lymphatic stages and so reaching the great lymphatic vein or the thoracic duct. This is early generalization. The bacilli are spread throughout the tissues; they will be gradually intercepted by the defensive elements of the RHS, leading to the formation of a large number of small tubercles, all at the same stage of development. These may take the form of a grey granulation or of Laennec's miliary tubercle and become localized in parenchyma rich in elements of the RHS, in the serous membranes, or in the lymph-nodes (see Fig. 1, 2). It is important to keep this stage of " acute miliary tuberculosis " in mind in meat inspection, since it very probably corresponds to the presence of bacilli in the blood and in the muscles. Nieberle [36] verified such a condition in 90% of cases of acute miliary tuberculosis. This early generalization corresponding to granulitis (Empis) may be fatal. Otherwise, the miliary tubercles lead to caseation and calcification or encystment.

Another possible development from the primary complex is " chronic tuberculosis of the organs ". It is observed particularly among adults, and

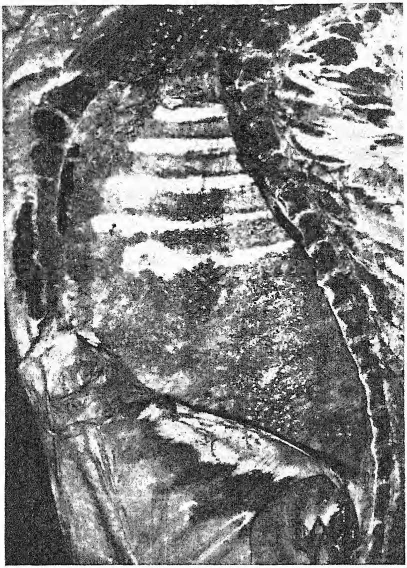
chiefly in cattle. Spreading from the primary focus, the tuberculous lesion gradually invades the organ by the canalicular (bronchi, bile ducts) or lymphatic route. This results in foci of caseous tuberculosis, sometimes taking the form of cavities or areas of softening, while the caseous lesions, dating from the primary infection, continue to grow in the associated

FIG. 3. CHRONIC TUBERCULOSIS IN COW



A = *caseous lymph-node in the mesenteric tissue*
B = *type of small tuberculous nodule frequently seen in various lymph-nodes in chronic tuberculosis ; these lesions may easily be missed unless multiple incisions are made.*

FIG. 4. TUBERCULOSIS OF PARIETAL PLEURA IN COW



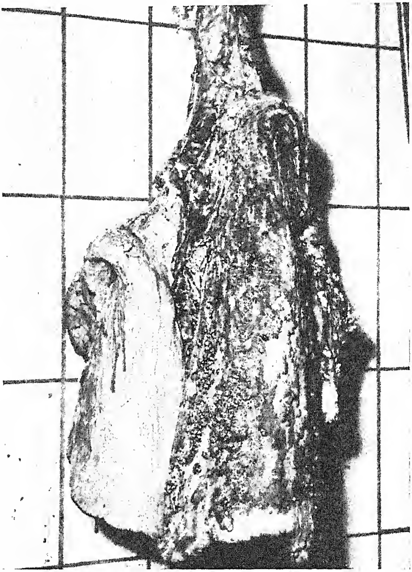
Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

lymph-nodes. In theory, no sign of haematogenous generalization is to be found in these forms—in particular, no lesions in the spleen, kidneys, bones, or meninges; it may be found, however, that the infection has spread into neighbouring tissues, giving rise to nodular lesions of the serous membranes, comparable to those in the lungs or liver.

Where tuberculosis has not progressed beyond the primary infection or chronic tuberculosis of the organs (see Fig. 3), it is a sign that the defences of the organism against the bacillus are strong and effective. At some time or other during the life of the subject, however, various factors—fatigue, gestation, lactation, deficiencies, parasitic infestation, nutritional disturbances, etc.—may lead to a decrease in resistance, thus enabling the ever-present bacillus to multiply and spread through the tissues from the

primary tuberculous focus. This is late generalization, resulting in lesions which indicate that the organic defences have collapsed. Such late generalization results, first, in Nieberle's *Niederbruchsformen*, hypo-ergic forms

FIG. 5. TUBERCULOSIS OF VISCERAL PLEURA IN COW



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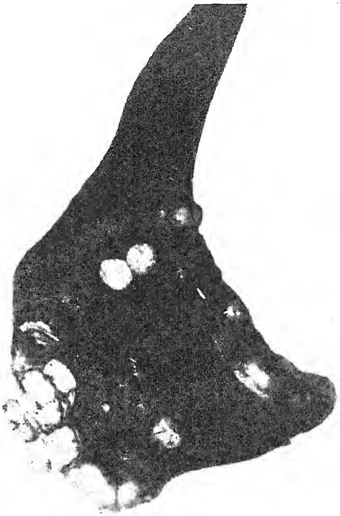
where exudative lesions predominate over nodular forms, i.e., massive caseous pneumonia or sarcomatous appearance, pleurisy (see Fig. 4, 5) or exudative peritonitis, caseous mastitis and metritis, multiple small caseous foci in process of softening in the organs (see Fig. 6). All this is accompanied by semi-caseous, hypertrophying lymph-nodes and, in general, congestion, oedema, or even haemorrhagic micro-foci bordering the caseous lesions. Similarly, acute miliary tuberculosis, typical of adults, is found with the appearance of multiple grey granulations in the

FIG. 6. SPLEEN OF HORSE WITH NUMEROUS TUBERCULAR FOCI: TYPICAL LARDACEOUS FORM OF TUBERCULOSIS



Kindly provided by Professor F. Schönberg, Institut für Lebensmittelkunde und Milch Hygiene, Tierärztliche Hochschule, Hanover, Germany

parenchyma (lungs, kidneys, liver, spleen, etc.), whereas formerly there had been only a quiescent primary complex or organized sequelae of early generalization.

Pathogenesis of Tuberculosis in Relation to Meat Inspection

From the point of view of meat inspection the pathogenesis of tuberculosis is important since, on the basis of the pathological nature of the lesions, the stages of the disease during which the tubercle bacillus temporarily passes through the blood-stream so as to bring about generalization can be identified. Clearly, meat from an animal slaughtered during such a critical stage is the type most dangerous for the consumer. Nieberle [36]

was able, by means of cultures and guinea-pig inoculations, to show in a considerable proportion of such cases that bacilli were present in muscles without lesions: 41 out of 47 characteristic *Niederbruchsformen*, 11 out of 20 cases in the initial stage of *Niederbruchsformen*, and 50 out of 100 cases of typical acute miliary tuberculosis. Thus it would seem possible for the meat inspector to base his decision essentially upon his analysis of the pathological characteristics of the lesions.

This would appear to be a logical scientific basis for the judgement of tuberculous meat, but it is open to a certain amount of criticism.

First, according to certain authors, particularly Meyn,[30, 31] a " slaughter bacteraemia " may arise at the time of death since, no matter how efficient the bleeding, about one-third of the total volume of blood remains in the tissues, so that the muscles may contain bacilli that have not given rise to lesions visible either to the naked eye or under the microscope. Secondly, it may be held that the classic formulae in respect of the development of tuberculosis are too rigid and certainly do not take in all active forms of the disease. It is perhaps premature to claim to have determined all phases in the extension of the disease and all routes whereby it may spread; moreover, the relative importance of the lymphatic system and of the blood-stream in the latter connexion is variously appraised by different authors. Thirdly, the risk of post-mortem contamination of the meat through tools that have been in contact with tuberculous foci rich in bacilli cannot be said to be negligible. Lastly, stress must be laid on the difficulties of interpretation involved in judging the infective power of meat by a method calling for a sound knowledge of the mode of development of the disease. Nevertheless, the risk associated with possible failures in the application of this method should not be exaggerated.

Research and experiment are now sufficiently comprehensive to justify the view that the possibility of infection through the digestive tract from meat carefully freed of tuberculous lesions is extremely small.

All the same, under practical conditions and bearing in mind the justifiable desire to save a large tonnage of animal protein from destruction, judgement of tuberculous carcasses on the basis of pathological examination appears to be the only rational method.

Unsuitability of Infected "Intermuscular" Lymph-nodes as Criterion for Determining Extent of Seizure

For a long time, the law of regional adenopathy was taken as a criterion, and carcasses or parts of carcasses were condemned when the so-called " intermuscular " lymph-nodes showed tuberculous lesions, irrespective of the pathological nature of the latter. According to regulations still in force in some countries, " tuberculosis " of a lymph-node requires the seizure

of the corresponding " region ". This amounts to saying that the finding of any tuberculous lesion whatsoever in a lymph-node signifies that bacilli are actually present in the muscle groups or tissues whose lymph drains into the node in question. In actual fact, this is probable only if the nature of the lymphatic lesion indicates a recent invasion of the lymphatic area by the tubercle bacillus, i.e., shows grey or new miliary tubercles or tumefied lymph-nodes with incomplete caseation, constituting the semi-caseous hypertrophying tuberculosis of Vallée & Chaussé [46] or Bongert's [5] lymphatic form with radiating caseation. A lymph-node affected by nodular caseous, caseo-calcareous, or fibro-caseous tuberculosis signifies, on the contrary, that it was attacked by the bacillus a long time previously when in transit through the respective lymphatic area. The muscle is not the sole constituent of this area and, if there is no sign elsewhere of late generalization, it is extremely improbable that it will still contain tubercle bacilli. In this connexion, investigation by means of cultures or inoculation has not been as extensive as would seem desirable. In personal research, however, carried out over a period of more than 20 years, it may be mentioned that some 50 cats or dogs were fed with muscle tissue, the corresponding lymph-node of which was affected with caseous, caseo-calcareous, or fibro-caseous tuberculosis, and not one of these animals contracted the disease. Authors are too exclusively concerned with identifying cases where the muscle may contain bacilli, whereas it would appear to be at least as important to determine those where the bacilli are indubitably absent. Further large-scale research on these lines might profitably be undertaken.

Another reason why tuberculosis of a lymph-node may no longer be regarded as an infallible sign of the presence of the bacillus in the corresponding muscle is that the lymph-gland may have been infected from other sources than the muscle, either directly through its own vascular system or from bones or joints also situated in its lymphatic drainage area.

Extent of Seizure according to Anatomicopathological Nature of Lesions

A careful study of the pathological characteristics of the carcass and of the sites of the tuberculous lesions should enable the meat inspector to trace the history of the disease. Even if the origin of the infection lies so far back as to make it impossible, particularly in the case of a dissociated primary complex, to discover the initial route of penetration of the bacillus, it is possible to decide at the time of slaughter whether generalization is recent or of long standing and whether it is of the early or late type.

The finding of miliary tuberculosis, with numerous tubercles all at the same stage of grey granulation or of miliary tubercle (acute miliary tuberculosis), should be regarded as indicating the development of a generalized

infection shortly before slaughter, whether these lesions are in a single organ or parenchyma or are found in various parts of the carcass. All sections of the carcass are then under suspicion of harbouring bacilli, and total seizure is necessary.

The same holds true when inspection reveals tuberculous lesions resulting from failure of the organic defences (*Niederbruchsformen*), for example, acute exudative tuberculosis of the serous membranes ; extensive lobar pneumonia ; sarcomatous bronchopneumonia ; caseous mastitis, metritis or nephritis ; or semi-caseous hypertrophying lymphatic tuberculosis (radiating). In these cases it is justifiable to suspect that, at the time of slaughter, bacilli were still in circulation in the animal body as a whole, and that the RHS defensive system had not as yet been able to intercept them. Lastly, it will hardly be disputed that total seizure should be the rule for all animals which are both tuberculous and cachectic, although cachexia is by no means always the result of tuberculosis. Nevertheless, cachexia alone, with no associated tuberculosis, will clearly justify total condemnation of a carcass.

In cases other than those described above the logical procedure is a simple extirpation of the lesions, carried out with all necessary precautions for thoroughness and avoidance of accidental contamination of meat to be supplied for consumption. In short, the so-called " partial " seizure of a carcass on account of tuberculosis of a regional lymph-node cannot be insisted upon since it has no logical foundation. The arbitrary nature of the partial seizures enforced hitherto is clear, moreover, to meat purchasers, and their commonsense refuses to accept the theory that a certain part of a carcass may be dangerous and unfit for consumption whereas an immediately adjacent part, identical in appearance, may freely be put on sale. The explanation advanced by the meat inspector to the effect that delimitation corresponds to the lymphatic areas of the infected glands is unconvincing. Furthermore, he is perfectly well aware that there is nothing less fixed than the boundaries of a lymphatic area, and that very probably such boundaries do not exist. When deciding the area subject to partial seizure, the inspector may very often in practice be guided by the traditional system of cutting up used by butchers which, of course, takes no account of the lymphatic system.

Special Cases : Lesions in Serous Membranes, Bones, and Viscera

Nevertheless, certain special cases have to be taken into account in respect of tuberculous meat, where total seizure is not justifiable.

Let us first take up the question of chronic tuberculosis of the serous membranes. In accordance with what has already been said, nodular

caseous, caseo-calcareous, or fibro-caseous tuberculosis, as well as organized exudative tuberculosis of the pleura or peritoneum, justify extirpation of lesions alone provided there is no other motive for total seizure. Chronic tuberculosis of the serous membranes might be thought to involve simply the excision of the membrane bearing the tuberculous foci. In fact, contamination would be unavoidable in the course of such a procedure. Moreover, it has been shown by Brandt & Hülphers [8] that the tissues adjacent to the serous membrane proper frequently contain bacilli. In the circumstances, it would appear advisable to condemn all the thoracic or the abdominal wall apart from the iliospinal and pectoral muscles. In the case of tuberculosis of the pleura or the peritoneum, removal of the diaphragm would seem advisable.

The second specific point for consideration relates to bone tuberculosis. The frequency of bone tuberculosis in the pig is well known, and it is not so exceptional in cattle as might be supposed. The bone-marrow constitutes an important part of the RHS. As such, it intercepts bacilli circulating during a generalization phase, the result being a bone lesion. This does not necessarily entail adenopathy of the nearest lymph-node: Haffner [22] has stressed the frequent absence of this condition, particularly in the pig. Nevertheless, in the long run, the lymph-node may become infected. Consequently, the finding of a lymph-node lesion at the time of slaughter may indicate, not that the muscle is infectious, but that there is an osseous focus, which can only be brought to light by breaking up the bone concerned. This is tantamount to saying that, although tuberculosis in the form of caseous, caseo-calcareous, or fibro-caseous nodules in a lymph-gland of a carcass does not automatically indicate the presence of bacilli in the corresponding muscles, it may, on the other hand, signify a hidden lesion in the neighbouring bone.

Furthermore, experience shows, particularly with the pig, that for every focus of bone tuberculosis immediately detectable on inspection,

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PLATE I

Fig. 1. Tuberculosis, acute bovine infection, of mesenteric lymph-nodes of pig. The haemorrhages and stellate caseation indicate activity of the lesions and are suggestive of a tuberculous bacteraemia.

Fig. 2. Tuberculosis, old-standing bovine infection, of submaxillary lymph-node of pig. Several anthracotic deposits can be seen.

Fig. 3. Tuberculosis, old-standing avian infection, of submaxillary lymph-node of pig. The node is enlarged and the caseous foci are putty-like, pin-head in size, and readily enucleated.

Fig. 4. Tuberculosis-like lesions of submaxillary lymph-node of pig caused by Corynebacterium equi. *The necrotic foci are surrounded by a connective tissue capsule and easily removed from the lymph-node tissue.*

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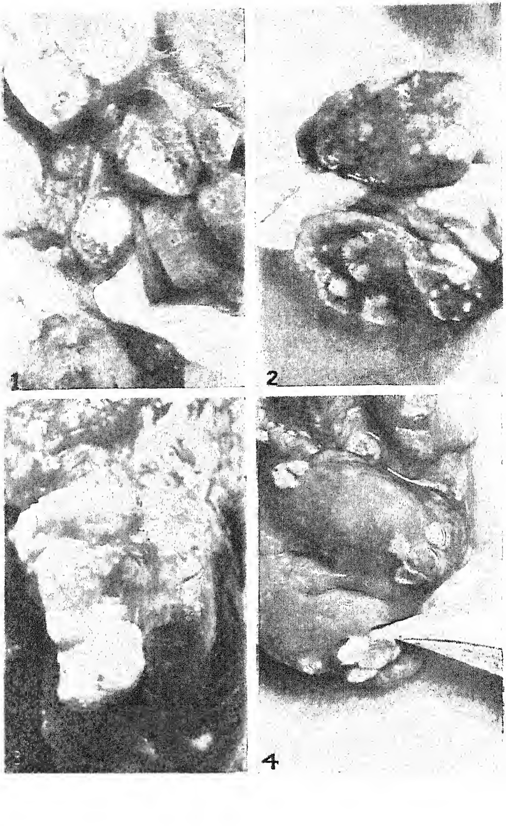

there are usually other bone lesions that careful fragmentation of the skeleton alone will bring to light. It would therefore appear legitimate, when lesions are found in the lymph-nodes of a carcass and there is no other cause to justify total seizure, to remove both the lesions and the skeleton as a whole. This safety measure, which involves complete boning, may appear severe from the viewpoint of the meat trader ; its consequences from the economic viewpoint, however, are extremely small when it is realized that in the end the greater part of the bones are used for industrial purposes.

Lastly, a third point needs discussion—namely, seizure of the viscera in the absence of any other cause for total seizure of a carcass. There can be no contesting that the complete seizure of a visceral organ showing a lesion, whatever the nature of the latter, is a wise precaution. On the other hand, the observations made concerning the muscular area of a carcass where the corresponding lymph-node is affected with chronic tuberculosis would seem, *a priori*, to be applicable also to viscera without apparent lesions but with a tuberculous lymph-node adjacent. However, the statistics previously mentioned show that, in an impressive number of cases, viscera with no lesions visible to the naked eye may contain microscopic lesions or even isolated bacilli. This is not surprising in view of the large number of RHS elements in most of the viscera. It would thus seem that greater severity is justified in the judgement of offal and that it is legitimate to call for the seizure not only of any organ bearing a lesion, but also of any organ which, although apparently healthy, has a lesion in the corresponding lymph-node.

Summary of Decisions which Can be Taken

In short, judgement of meat from mammalian tuberculous animals, based on a thorough study of the pathogenesis of the tuberculous infection through careful analysis of the site and pathological characteristics of the lesions, may be summarized as follows :

Total seizure (carcass and viscera) in the following cases :

(*a*) tuberculosis in any form, where accompanied by cachexia (whatever the latter's cause) ;

(*b*) acute miliary tuberculosis characterized by the existence of multiple grey granulations or miliary tubercles all at the same stage, irrespective of site ;

(*c*) tuberculous lesions indicating a recent collapse of the organic defences, i.e., generalized acinous tuberculosis of the lungs ; bronchopneumonia of sarcomatous appearance ; massive caseous tuberculosis of

an organ; acute exudative tuberculosis of the pleura, peritoneum. pericardium, or meninges; or semi-caseous, hypertrophying, lymphatic tuberculosis.

Free disposal of the carcass in all other cases, subject to careful extirpation and destruction of all tuberculous lesions. Tuberculosis in a lymph-node or bone calls for complete boning and destruction of the whole skeleton.

Tuberculosis of a serous membrane demands the seizure and destruction of the wall of the corresponding cavity, with the exception of the muscles covering the outer side of the wall.

Seizure, rendering, and destruction of any organ with a tuberculous lesion, even where clearly delimited, or where the corresponding lymph-node has a tuberculous lesion, irrespective of its nature.

Tuberculous Poultry

Although danger to man from the avian bacillus is extremely small, the frequent presence of large numbers of bacilli in the muscles of tuberculous poultry, the habitual cachectic state of the carcasses of such birds, and their low commercial value should encourage severity. Accordingly, the total seizure of tuberculous poultry would seem to be called for in all cases.

Sterilization of Tuberculous Meat

Total seizure, in the cases mentioned under (*b*) and (*c*) above, applies to carcasses of animals which are well, or even very well, fattened. In such carcasses, the muscular masses of the neck, shoulder, dorso-lumbar region, pelvis, and thigh cannot cause repugnance provided they are free from lesions, any more than can the presence of trichinosis or sarcosporidiosis, since there is absolutely no difference in appearance to similar meat from a tuberculosis-free animal. Furthermore, the food value of this meat is undeniable.

Consequently, it would appear legitimate and desirable for a muscular tissue of this kind to be released for consumption after treatment to ensure destruction of any bacilli it may contain. There is indeed no objection to such meat being put on the market after proper sterilization. The sale of confiscated meat for consumption after suitable sterilization, provided it is found to be sufficiently nutritive, is accepted almost unanimously in principle and is legal in a number of countries. The health of the public is completely safeguarded by sterilization in such cases, and Cesari [12] is right in advocating the extensive adoption of this practice.

Obviously meat to be sterilized should first be cut up thoroughly so as to discover and eliminate any macroscopic lesions. At the same time, any suspect part should be removed, together with anything of low food value (tendons, fascia, serous membranes, large vessels, lymph-nodes, bones, etc.).

The only existing method of sterilization that offers a complete guarantee is treatment by heat, which is unfortunate from the commercial viewpoint. In several countries, such as France, where the sale of inferior meat has never become popular even in periods of extreme shortage, butchers are not eager to offer for sale meat treated in this way, nor is the public itself particularly anxious to buy it. Consequently, research to find an effective method of sterilization that would keep the normal raw appearance in the meat would be highly desirable (ultrasonics, diathermy, etc.).

Marketing of Sterilized Meat

It is stipulated in the legal regulations of some countries that sterilized tuberculous meat must be sold under a name that more or less clearly indicates its origin. One may well ask whether this discriminatory measure, which may engender unjustified repugnance in the consumer, is really necessary. Why take such a precaution in regard to tuberculous meat when it is not deemed necessary for other causes of total seizure (pork "measles" or trichinosis) or of partial seizure (tumours or chronic arthritis, for example) which, if known, would arouse equal repugnance. And again, why should it not be required to specify the origin of meat from tuberculous animals released for consumption after removal of the lesions ?

Certain regulations also prohibit the use of sterilized tuberculous meat in making up processed or cooked meat products. Why should such provisions, if they are prompted by the desire to prevent fraud concerning the origin of the food, be restricted solely to tuberculous meat ?

This kind of stigma on tuberculous meat that the inspector considers fit for consumption after sterilization is unjust, the more so since certain authors even go so far as to express the view that sterilization in this instance is an excessive precaution. The opinion of Leclainche [28] expressed in 1898 should be borne in mind—namely, that it has never been satisfactorily proved by experiment that the consumption of meat from tuberculous cattle is capable of causing tuberculosis.

In these circumstances new and exhaustive research would seem to be desirable in order to find out whether ingestion of untreated meat from those parts of a tuberculous carcass that are free of lesions involves a real danger, however small, of transmitting tuberculosis to the consumer.

In the meantime, sterilization should remain in force, but that is not to say that it always will.

Technique of Inspection of Tuberculous Carcasses

Some detail needs to be given of the technique to be used by the inspector in examining the carcass of a tuberculous animal.

In the examination of the carcass of any slaughtered animal, the first move is to look for signs of tuberculous infection. The established criterion for this is the presence of a lesion in the left tracheobronchial lymph-node ; and many inspectors consider it axiomatic that no lesion in this site is equivalent to absence of tuberculosis. This is true in 99% of cases, but there are exceptions to the rule. A rigorous search should be made in all four possible sites of a primary complex, i.e., lungs, pharynx, intestines, and umbilical region. The law of parallel adenopathy has no exception in so far as a primary complex is concerned. Moreover, in the case of a dissociated primary complex there is invariably a lymphatic lesion. The inspector can therefore confirm the absence of tuberculosis only where no lesions are found in the following sites, all of which should be systematically examined : all lymph-nodes of the lungs and mediastina ; the retro-pharyngeal, subglossal, pterygoid, and pre-atlantoid lymph-nodes ; and lymph-nodes of the two mesenteric chains and of the liver. It need hardly be said that the inspector cannot claim to have carefully examined these glands unless he has made absolutely as many sections of each one as is possible.

Apart from visible lesions, congested lymph-nodes (Vallée) should be considered suspect where they show on section that contrast between the cortical and medullary zones has disappeared or that the lymph follicles tend to stand out on the surface of the skin in a greyish-white mass. Where a lesion is discovered in one of the test lymph-nodes for primary complex, the carcass and viscera should be subjected to methodical inspection, including the udder, uterus, and nerve-centres. The order in which this inspection is carried out is of little importance provided it is done systematically. The serous membranes and all other lymph-nodes of the carcass should be carefully examined. If the kidney has been left adhering to the lumbar vault, it should be freed from its outer layer of fat, the lymph-node examined, and the parenchyma cut into if necessary. As regards the viscera, careful examination of their lymph-nodes is the best source of information.

The inspector should note the site and also the pathological characteristics of the lesions, as, for instance, whether they are acute miliary,

chronic miliary, caseous, caseo-calcareous, softened caseous, infiltrating or radiating caseous, fibro-caseous, acute exudative, organized exudative, etc.

Differences of opinion in classifying lesions may exist and the difficulty of establishing pathological standards to ensure uniform classification must be acknowledged. It would accordingly be highly desirable if expert pathologists could exchange views on this matter, with the object of preparing a booklet, illustrated in colour, which would be distributed to inspectors and would serve as a guide in doubtful cases and lead to the essential unanimity of verdict.

Nevertheless, pending the publication of such a guide, the inspector should be able, on weighing up his findings as a whole, to form an opinion which is satisfactory from the scientific viewpoint on the existence in an animal of recent generalized tuberculosis or of imminent generalization of the disease consequent upon the collapse of resistance in the infected animal. The decision as to the extent of seizure or sterilization will follow from this opinion in accordance with the principles set out above.

Conclusions

In conclusion, it should again be stressed that the reason why tuberculous meat is still a problem of undeniable importance at the present time, from the viewpoint both of public health and of world economy, is the persistence in many countries of an alarming percentage of tuberculous animals among livestock. A systematic campaign against animal tuberculosis under the auspices of international bodies, aimed at eradicating this scourge in every country of the world, would appear to be the only way of effecting a radical change in the situation.

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POST-MORTEM INSPECTION AND JUDGEMENT OF PARASITE-INFECTED CARCASSES

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The prevalence of parasites in domestic animals and game requires that special attention be paid to parasitic infection when inspecting meat. This is essential for two reasons. First, the primary aim of meat inspection is to ensure for the public supplies of sound, good-quality meat. Hence, every precaution must be taken to make certain that no harmful parasites are present in any meat that is passed for human consumption. Secondly, where parasitic infestation is found in a slaughtered animal, the breeder may be alerted and thus enabled to institute control measures, in the same way as information passed to public veterinary authorities is used in the control of infectious diseases in animals. The economic importance of this is, of course, obvious.

Parasitic infestation may be discussed under three headings:

(*a*) parasites not transmissible to man;

(*b*) parasites indirectly transmissible to man by change of the host; and

(*c*) parasites directly transmissible to man by the consumption of meat.

Parasites not Transmissible to Man

The importance of this group lies in the fact that the presence of these parasites in the animal may produce a carcass and viscera so repulsive in condition as to make it inedible.

Parasites of the skin

The numerous parasites that infest the skin need not be considered here, except for those of the pig; the skin of other animals is not ordinarily used for human food.

Demodex folliculorum var. *suis*, found mostly in the sebaceous glands, may give rise to pustules and nodules up to the size of a hazel nut. containing a pus-like substance. The resulting condition is known as "shotty eruption" of the pig's skin. These parasites usually select areas where the skin is thin. Often the nodules become ulcerated and show little tendency to heal. *Coccidium fuscum* may also be mentioned as a causative agent of "shotty eruption".[59]

Parasites of the subcutis

Cattle. Warble-fly larvae (*Hypoderma bovis* and *H. lineatum*) in their migrations and long stay under the skin produce a yellowish oedema in the subcutis of heifers, especially on the chine, many weeks before they leave their sites. The condition is known as "licked" beef or "butcher's jelly".

According to the works of Omo,[30] the warble-fly larvae excrete a so-called hypoderma toxin during migration and perforation of the skin.

Poultry. A very common mite in the fowl and pheasant is *Laminosioptes cysticola*, which normally inhabits the subcutaneous tissue of these birds. After death this mite is surrounded by a wall of calcareous salts and appears as a white spot varying in size up to a grain of wheat. Another mite, *Cytoleichus nudus*, living in the air-sacs and lungs, may cause local inflammation.

Parasites of the mucous membrane

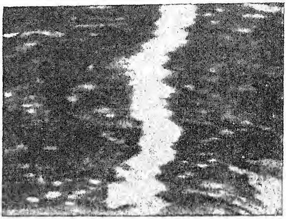
Horse. The larvae of the horse bot-fly (*Gastrophilus intestinalis*) are sometimes found in the pharynx but more often at the pyloric zone of the stomach. This parasite is very common in horses kept mostly at pasture. It sometimes causes anaemia and colic.

Sheep. The larvae of the sheep bot-fly (*Oestrus ovis*) are harboured in the nasal cavities and sinuses for several months. As a result, purulent inflammation sets in, occasionally involving serious changes in the adjacent membranes of the brain.

Parasites of the muscular tissue and internal organs

Protozoa. The *Sarcocystis* genus, in its various forms, inhabits most kinds of animals, except the horse (*S. bertrami*), where it is found but rarely. Its sites of choice in cattle (*S. blanchardi*) and in sheep and goats (*S. tenella*) are the musculature of the oesophagus, the tongue, the pharynx, the larynx, and the diaphragm and skeletal muscles. In young heifers, the longissimus dorsi and semitendinosus muscles are especially affected, and in the pig (*S. miescheriana*)—where it is very common—the muscles

FIG. 1. SARCOSPORIDIA CYSTS IN MUSCLES OF PIG



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of the diaphragm, abdomen, and larynx are the predilection sites (see Fig. 1). Schönberg[45] has drawn attention, too, to a form of myositis (myositis sarcosporidica), which is caused by these parasites.[62]

Eimeria is a genus of sporozoa that causes severe damage in the intestine of young cattle (*E. zurnii*), sheep and goats (*E. faurei* and *E. arloingi*), and young pigs (*E. debliecki*). In baby chicks (*E. tenella*), it affects the caecum, and gives rise to inflammation in older birds (*E. acervulina* and *E. maxima*). *E. stiedae*, a parasite of rabbits and hares, is found in the liver, where it causes white nodules to develop along the bile-ducts, in size up to a grain of wheat.

Among the Haemosporidia found in Europe, *Babesia bovis* alone plays some role, being the causal agent of redwater fever in cattle in some areas of Germany, Sweden, Finland, Great Britain, and Ireland.

Nematoda. Of the nematodes, special attention has to be paid to the Ascaridae, the nodule-forming genus *Oesophagostomum*, and *Trichuris*, all intestinal parasites, and *Metastrongylus*, found in the respiratory tract.

From the point of view of meat inspection, note should be taken of any damage to the liver and lungs caused by migrating larvae, such as multiple indurated areas of proliferated connective tissue ; and secondly, in veal, of any odour resembling the smell of volatile fatty acids, a condition caused by infection with *Ascaris vitulorum*.

Platyhelminthes. All the cestodes come into this category of parasites, with the exception of *Taenia echinococcus* of the dog. They are :

Anoplocephala (horse) and *Moniezia expansa* (ruminants), the cystic stage of both of which is found in pasture mites ;

Diphyllobothrium latum (pig), which occurs in areas where fish are fed to pigs, the cystic stage inhabiting fish and water-fleas ;

Taenia pisiformis (carnivora), the cystic stage of which (*Cysticercus pisiformis*) inhabits the liver, omentum, mesentery, lungs, and brain of rabbits and hares ;

Taenia serialis, the cystic stage of which (*Multiceps serialis*) inhabits the subcutaneous and intermuscular tissue of rabbits ;

Taenia hydatigena, the cystic stage of which (*Cysticercus tenuicollis*) is found in the liver and serous membranes of cattle, sheep, pigs, and wild ruminants;

Taenia ovis, the cystic stage of which (*Cysticercus ovis*) is found in the intermuscular tissue of sheep and goats;

Multiceps multiceps, the cystic stage of which (*Coenurus cerebralis*) occurs in the brain of sheep and cattle;

varieties of *Cittotaenia* and *Andrya* (rodents), the cystic stages of which are found in pasture mites;

tapeworms belonging to the genera *Davainea*, *Raillietina*, *Hymenolepsis*, etc. (poultry), the cystic stages of which are harboured by flies, beetles, and earthworms.

Among the trematodes, *Fasciola hepatica* is found in the liver of cattle, sheep, goats, game, pigs, horses, hares, rabbits, and man, and *Dicrocoelium dendriticum* in the liver of cattle, sheep, hares, and rabbits.

The lesions produced in the liver vary in type. Whereas the fullgrown parasites damage the bile-ducts, the migratory stages cause inflammation and mechanical injury of the liver parenchyma.

The rare cases of liver-fluke infection in man are not caused by the transmission of the eggs or adult parasites, but by the ingestion of cercarial cysts attached to blades of grass.

Judgement of infected meat

Where the parasites can be removed and the infected organs show no sign of change, there is no justification for condemnation. Where, in cases of fascioliasis, the changes are confined to the bile-ducts only, the central parts of the liver should be removed. Livers containing cirrhotic or considerable sanguinary areas must be condemned.

The areas of the skin of pigs showing " shotty eruption " should be removed. The subcutaneous oedema caused by the larvae of the warble fly should be scraped off and, if necessary, affected areas should be dried by the application of a linen cloth for 24 hours. An oesophagus so affected that the larvae cannot be removed should be destroyed.

Localized areas affected by sarcosporidiosis, e.g., in the diaphragm or oesophagus, may be removed. In a generalized infection, the whole carcass should be condemned with the exception of the edible fat. In cases of coccidiosis, the carcass may be passed for human consumption provided it is not in a poor or oedematous condition. The livers of rabbits or hares affected with liver coccidiosis must be destroyed. Where an animal slaughtered in the early stages of redwater fever is well nourished, the carcass may be passed for consumption; otherwise, the judgement

should be conditional release or condemnation, depending on the stage of the disease and the state of the animal. Intestines harbouring worms, but showing no pathological changes such as inflammation or thickening or nodulation of the walls, may be released for use. Areas of the liver showing migratory damage should be removed; the carcasses of calves, but not of pigs, infected by *Ascaris* must pass the boiling test used to detect abnormal odours in the meat.[59] Lungs showing evidence of worm migration or presence of lung-worms of any kind must be destroyed, as also the whole of any carcass where tapeworms in the cystic stages are found.

Parasites Indirectly Transmissible to Man by Change of Host

Tapeworms

Echinococcus granulosus is an intestinal parasite of the dog and fox (2.5-5 mm in length, with 3-4 segments), often present in very large numbers. It is found in the cystic stage in cattle, sheep, and pigs, appears seldom in the horse, and is also found in man. The echinococcus or hydatid cysts appear as *E. unilocularis* and *E. multilocularis* (see Fig. 2).

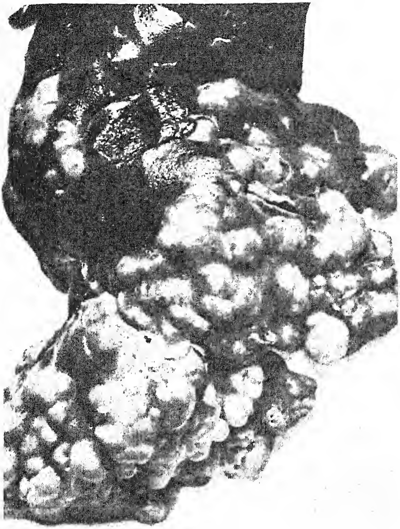
Hydatid disease in man is most extensive and may be endemic in countries raising large numbers of sheep, one of the common reservoirs of the echinococcus. Although human infection may originate with contaminated animal products, hides or wool of herbivora, or contaminated environment, man is most commonly infected by ova of the echinococcus from dogs which have acquired the parasite by eating infected carcasses of sheep or other animal reservoirs of the hydatid. Personal hygiene, particularly washing of hands before eating, is important and in France the infection is called " disease of the soiled hands ".[33, 63]

Judgement of infected meat. Viscera containing hydatid cysts must be removed and destroyed in such a way that neither dogs nor other animals can have access to them. Thornton [59] states that the cysts remain alive for nine days in the lungs and seven days in the liver of buried sheep. In unburied viscera at normal temperature, destruction is not complete before the expiry of one week. Where the musculature is found to be infected or signs of emaciation are apparent, the destruction of the whole carcass is indicated.

Mites

Linguatula rhinaria inhabits the nasal cavity of dogs and is also sometimes found in humans. The larval form inhabits the mesenteric lymph-nodes, the liver, and the lungs, and sometimes the kidneys and spleen as well, of cattle, sheep, goats, pigs, hares, and rabbits, producing green

FIG. 2. EXTENSIVE HYDATID INFESTATION OF LIVER OF PIG



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or yellowish nodules. Direct infestation of man by the ingestion of larvae or of eggs from dogs has been recorded.

Judgement of infected meat. The larval foci must be excised from the respective organs and the damaged lymph-nodes removed. The feeding of infected gut to dogs should be avoided.

Parasites Directly Transmissible to Man by Consumption of Meat

Diphyllobothrium latum

This is a parasite of man, dogs, cats, and foxes. The cystic stages of development are passed in water-fleas and subsequently in freshwater fish,

such as trout and pike. Von Ostertag[31] has reported one case of cysts found in the musculature of a pig. The larvae die at a temperature of 122°F (50°C) within a few minutes, but are transmitted to man by eating undercooked or raw fish.

The main clinical sign in affected persons is a pronounced anaemia.

Judgement of infected meat. Fish harbouring cysts of this parasite should be destroyed.

Cysticercus bovis

This is the cystic stage of *Taenia saginata* in man. It is found in the muscles of cattle of all ages. *Taenia saginata*, also known as beef tapeworm, appears to be more or less widespread all over the world. Worm infestation results from eating undercooked or raw beef.

The main foci of infection are the skeletal and heart muscles, and the lungs, the liver, the brain, and the lymph-nodes. A greater frequency is found in young than in adult animals. The predilection sites are the masseter muscles, the heart (see Fig. 3, 4), the muscles of the neck and

FIG. 3. HEART MUSCLE OF COW SHOWING FRESH CYSTS OF CYSTICERCUS BOVIS

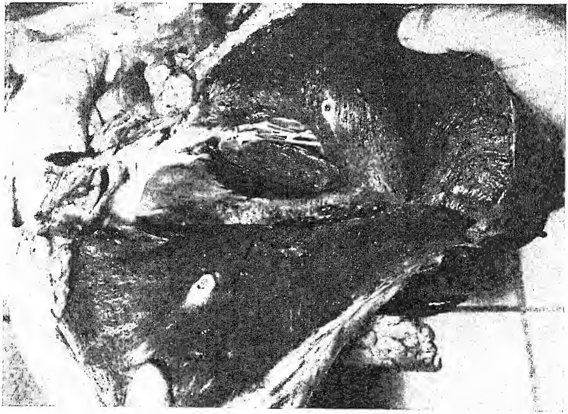

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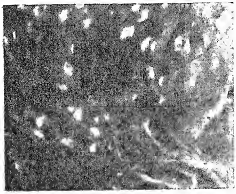
FIG. 4. HEART MUSCLE OF COW SHOWING CASEOUS CYSTS OF CYSTICERCUS BOVIS



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shoulder, the intercostal muscles (see Fig. 5), the adductor muscles of the hind legs, and the muscles of the diaphragm and the oesophagus.

There are two possible main routes of dissemination of the ova; first, through farmhands infected with tapeworms failing to remove all traces of their faeces before feeding calves; and, secondly, by contaminated pastureland, polluted by sewage or floodwater. It is notable that infection in calves is generally heavy, even where they are exclusively milk-fed, whereas in older cattle the cysticercus is found in moderate numbers only. The reason for this may be that a considerable dilution of the egg concentration takes place in the contaminated pastures. In this connexion, it should be borne in mind that the eggs remain infective for 71 days in liquid manure and for 159 days in pasture (Thornton [59]). Slaughterhouse statistics from various countries in Europe [4, 32, 52, 55, 58, 59, 66] confirm that the incidence of *Cysticercus bovis* has risen in the past few years, and general reports indicate a marked increase in cysticercosis from this source.[52]

Methods of detecting Cysticercus bovis *infection*. Parallel incisions are made through the internal and the external masseter muscles (see Fig. 6). Where infection is suspected in calves, an additional inspection of the heart is indicated, including opening of the ventricles.

As *Cysticercus bovis* tends to undergo degenerative changes, tests of viability are of great importance. By placing the cysticerci in normal saline solution at a temperature of 37°-40°C, (98°-104°F), to which some drops of ox-bile (30%) or pig-bile have been added, the scolex is evaginated within one to two hours.[2, 10, 12, 23, 28, 29, 35, 36, 37, 38]

Judgement of infected meat. German legislation (Schönberg & Zietzschmann [48]) makes a distinction between heavy infection, where more than

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PLATE II

Fig. 1. Sarcocyst (S. miescheriana) *in abdominal muscle of pig.* × 30

Fig. 2. Degenerated Cysticercus bovis *in masseter muscle of ox.* × 2

Fig. 3. Unilocular hydatid cysts in liver of pig.

Fig. 4. Melanotic deposits in lung of calf.

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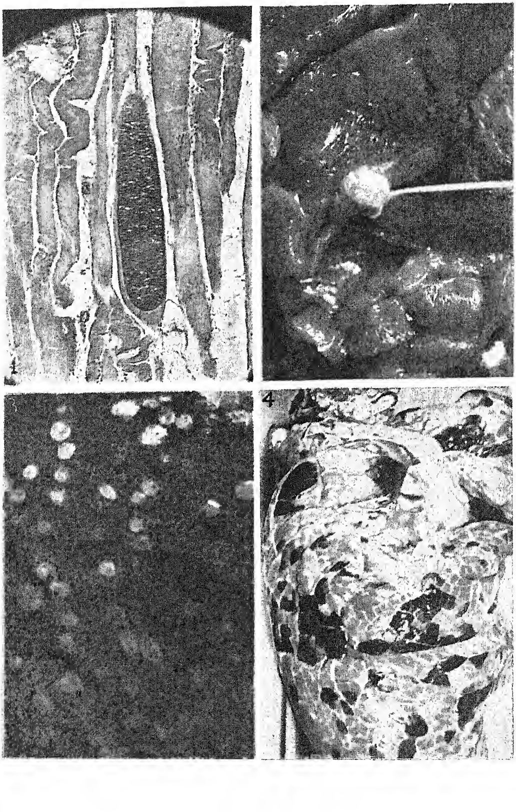
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FIG. 5. DIAPHRAGM OF OX WITH SEROSA REMOVED: NUMEROUS SPECIMENS OF CYSTICERCUS BOVIS

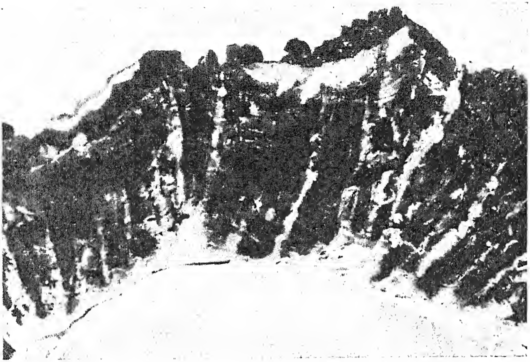

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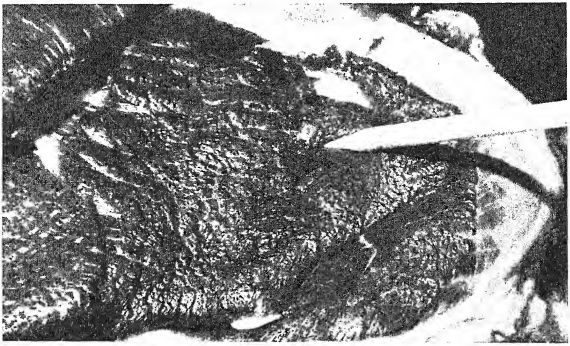
FIG. 6. EXAMPLE OF CYSTICERCUS BOVIS SHOWN AFTER INCISION OF MASSETER MUSCLE



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one cysticercus is found in the majority of the incisions made in the muscles of predilection, or where the flesh is discoloured or oedematous despite the presence of fewer cysticerci, and slight infection.

For heavy infection, the whole carcass is subject to condemnation, with the exception of the fat, the stomach, and the intestines, provided no cysticerci are found in these sites. The blood and the bones may also be released for use. For slight infection, the meat has to be cooked before release to the public or frozen to –3°C (26°F) for at least 24 hours, or salted for 21 days.[15, 65, 67] Swiss regulations [53, 54] make the same distinction but the requisite measures for sterilization are more severe. The meat may be sterilized by steam at a pressure of 1.5 atm. for two hours, or maintained at a maximum temperature of 4°C (39°F) for 21 days, or refrigerated until the internal parts of the carcass will remain frozen for at least 10 days. Pickling has to be for a period of three weeks. (See also Annex 13 (page 444) on temperature control and salt treatment of meat containing trichinae or cysticerci.)

Cysticercus cellulosae *

Man is the only known definitive host ** of *Taenia solium*, of which *Cysticercus cellulosae* is the larval stage. The latter is found mainly in the pig, but it has also been recorded in the dog, cat, rat, monkey, and bear. Auto-infection may take place in humans, either by contamination from the person's own faecal material or through the passage of eggs to the stomach by antiperistaltic movements of the small intestine and the subsequent dissolution of the membranes of the ova in the gastric juice. These cysticerci are often localized in the brain and in the eye, causing central disturbances and loss of vision or even of the eye itself. In the pig, the musculature of the heart, the intercostal and abdominal muscles, the muscles of the neck and shoulder, the diaphragm (see Fig. 7), and the tongue are the predi-

FIG. 7. DIAPHRAGM OF PIG HEAVILY INFESTED WITH CYSTICERCUS CELLULOSAE

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* See also the first report of the Joint FAO/WHO Expert Committee on Meat Hygiene (*Wld Hlth Org. techn. Rep. Ser.* 1955, No. 99).

** Definitive host is the host in which the sexual stages of the parasite develop.

FIG. 8. METHOD USED IN A CENTRAL AMERICAN COUNTRY FOR PALPATION OF TONGUE OF LIVE PIG FOR CYSTICERCUS CELLULOSAE CYSTS

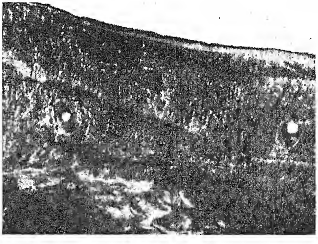
A metal bar is inserted into the mouth to enable the tongue to be withdrawn and palpated.

Kindly provided by Dr. H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

lection sites. French authors cited by Thornton[59] found the heart affected in 80% of the infections, the diaphragm and internal masseters in 50%, and the tongue in 40%, whereas the liver, lungs, kidneys, brain, and eyes ranged far behind the above-named sites. The number of cysts present varies from a few up to several thousands per kilogram of meat.

Cysticercosis in pigs is extremely rare in Great Britain, Germany, Denmark,

FIG. 9. TWO SPECIMENS OF CYSTICERCUS CELLULOSAE IN TONGUE MUSCLES OF AN INFECTED PIG



Kindly provided by Professor F. Schönberg, Institut für Lebensmittelkunde und Milch Hygiene, Tierärztliche Hochschule, Hanover, Germany

and the USA. The incidence in Germany in 1937 was 0.0002%, whereas in the Balkans, Portugal, and certain regions of South Africa, 10% to 15% of infected pigs have been recorded. In the period 1947-51, no case of *C. cellulosae* was found in the slaughterhouse at Basle.[55] The reports from other European countries also show a marked decrease in the incidence of this parasite. Inspection methods for detection are the same as in the case of *C. bovis*. The heart, tongue (see Fig. 8, 9), and larynx, the abdominal muscles, and—in view of the findings of the French authors referred to above—the muscle of the foreleg of pigs as well, must be examined, if necessary, by incision.[27, 48]

Judgement of infected meat. The same principles obtain as for meat harbouring *C. bovis*, except that, in lightly-infected cases, the carcass as well as the fat must be cooked, autoclaved, or pickled for three to four weeks. Freezing is not applicable.[53, 54]

Trichinosis *

Trichinella spiralis is found in the muscles of the pig, wild boar, bear, cat, dog, and various other carnivorous animals. After ingestion by man of infected meat, usually raw or rare, the cysts of the parasite are digested out in the stomach and, after excysting in the duodenum, the larvae develop in the mucosa of the duodenum and jejunum into adult males and females (see Fig. 10). After fertilization, the female deposits larvae during a period of six weeks on an average, one female discharging not less than 1500 progeny. Larvae reach the arterial circulation within 7-21 days and may become lodged in various body tissues, but are capable of further development and encystment only in skeletal muscles, the sites of choice being the diaphragm, the intercostal biceps and deltoid muscles, and the muscles of the tongue, larynx, and eyelids. Encystment is complete 35-40 days after invasion of the muscles. Calcification usually occurs within 6-9 months (see Fig. 11).

The minimum number of trichinellae needed for a successful infection vary from 15-25 for the cat and dog and 50 for the pig, to 50-75 for man. The numbers found in the muscles of pigs range from 300 up to 12 000 per gram. According to Craig,[9] 10 larvae per g are lethal.

The viability of the trichinellae lasts for the entire lifetime of the animal host; in humans, a period of 40 years has been recorded. After heavy infection, clinical symptoms occur in animal and man from the fifth day. According to some authors, the onset of symptoms in man usually occurs on the ninth day—the variation is from 2 to 28 days—but in heavy infections gastro-intestinal symptoms may occur within 24 hours. Mortality

* See also the first report of the Joint FAO/WHO Expert Committee on Meat Hygiene (*Wld Hlth Org. techn. Rep. Ser.* 1955, No. 99).

in the human may reach 30%, and after serious illness convalescence is very long.

The statistical data available, although incomplete, show that trichinosis caused by the consumption of meat and meat products is a considerable menace to human health. Methods in use at present for the detection of the infection in living animals (serological tests, intracutaneous and scarification skin-tests, eosinophil cell-count of the blood) do not give satisfactory results. Direct examination of meat with the trichinoscope would therefore still appear to be necessary (see Fig. 12). In Germany this has been compulsory in respect of pig carcasses since the last century; it is also obligatory in Denmark for sows and boars and for all pig carcasses 100 kg or more in weight.[1, 5, 8, 24, 40, 41, 42, 43, 44, 46, 47, 49, 51, 60, 63]

FIG. 10. TRICHINELLA SPIRALIS, WITH POLAR FAT ACCUMULATION

Kindly provided by Professor F. Schönberg, Institut für Lebensmittelkunde und Milch Hygiene, Tierärztliche Hochschule, Hanover, Germany

On the other hand, there is also the view, held in the USA for instance, that the examination procedures at present used in Europe are not practicable for rapid processing of pork, and that general measures regarding the feeding of pigs and the deep-freezing of the meat are preferable as a safeguard against the transmission of trichinosis to man.[50, 64]

Judgement of infected meat

Examination of pork for trichinae is not compulsory in the USA. United States regulations require that almost all processed pork products should be treated to destroy possible live trichinae. The exceptions are very few, and they include bacon, fresh pork sausage and similar breakfast sausage, hams, and pork shoulder-cuts that have been cured, but not smoked or otherwise processed. Methods of treatment include heating, refrigeration, and curing processes; for example, in smoked hams a temperature of not less than 137°F (58°C) must be obtained in all parts of the muscle tissue (the

FIG. 11. COMPLETELY CALCIFIED TRICHINELLA CAPSULE IN PIG MUSCLE

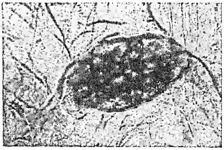


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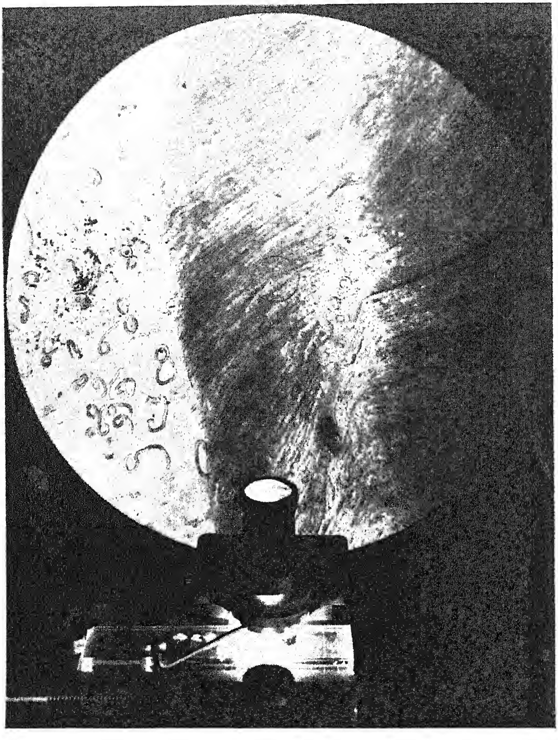
FIG. 12. EXAMINATION FOR TRICHINA WITH THE LEITZ ILLUMINATED TRICHINOSCOPE



Kindly provided by Professor F. Schönberg, Institut für Lebensmittelkunde und Milch Hygiene, Tierärztliche Hochschule, Hanover, Germany

upper thermal death-point for *T. spiralis* is 131°F (55°C)). For low-temperature treatment, the temperature on the outside of the containers for cuts of pork not over 6 inches (15 cm) thick must be 5°F (–15°C) for 20 days, –10°F (–23°C) for 10 days, or –20°F (–29°C) for 6 days. Gould & Kaase [14] have shown that very low temperatures may destroy the trichinae rapidly, thus a temperature of –36°F (–38°C) maintained for two minutes at the centre of the meat will kill larvae.

Sausage meat must be salted in pieces not exceeding a maximum diameter of 3/4 inch (2 cm), using 3½ lb. (1½ kg) of salt for 100 lb. (45 kg) of meat and storing for 20 days at a temperature not lower than 45°F (7°C)).[26]

The recommended treatment for hams is dry-curing for 40 days at a maximum temperature of 36°F (2°C) (Thornton [59]).

In some European countries, examination of pork-meat for the presence of trichinellae is compulsory. Much experimental work has been done, too, to evolve methods that will give the best and safest results in the destruction of muscle trichinellae under practical conditions.

Gould & Kaase [14] recommended refrigeration as follows for the destruction of muscle trichinellae :

36 hours	at	–27°F (–32.8°C)
24 ,,	,,	–30°F (–34.4°C)
7 ,,	,,	–33°F (–36.1°C)
40 minutes	,,	–35°F (–37.2°C)
2 ,,	,,	–37°F (–38.3°C)

Kasecker [17] obtained immediate destruction of larvae when meat was heated to 60°C (140°F), refrigerated for 10 days at a temperature of –17.8°C (0°F), or pickled in a 13% salt solution for 10 days. He found smoking inadequate for the purpose.

On the other hand, the following findings must be taken into consideration. Ransom [34] found that after a 20-day refrigeration process at 10°F to 15°F (–9.4°C to –12°C), not all trichinellae were dead, whereas no trichinellae were found living after refrigeration for 20 days at 5°F (–15°C) or after six days at 0°F (–17.8°C).

Küppelmayr [19] tested the efficacy of pickling in 7.9% and 12.5% sodium chloride for 20 days and found trichinellae still living. The addition of sodium borate seemed to diminish the efficacy of the pickling solution. Furthermore, experimental work has revealed gaps in existing knowledge regarding the effect of the speed of freezing, cooling, and thawing on the marketable quality of meat. In future research on freezing techniques for the control of trichinosis and cysticercosis, this aspect should not be overlooked.

Judgement of trichinella-infected meat in Germany by macroscopic inspection is based, in the first instance, on the condition of the meat and not on the number of trichinellae present. As a rule, the whole carcass is declared conditionally fit for consumption, with the proviso that the meat be cooked for $2\frac{1}{2}$ hours in cuts not exceeding a maximum diameter of 10 cm. Alternatively, sterilization may be employed. If the meat shows changes that are visible to the naked eye, the whole carcass has to be destroyed, with the exception of the fat, which may be rendered down for human use.[21]

Conclusions

There is no doubt that cysticercosis due to *C. bovis* is on the increase in Europe. Hence, severer measures respecting this aspect of meat control are indicated. Further steps are needed to secure improved personal hygiene among stock attendants, and better sanitary conditions on farms in general.

Trichinosis is a perpetual menace to the population as a whole. Both of these diseases have taken on an added importance in recent years, on account of the tendency towards increased consumption of raw or lightly cooked meat and sausages.

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APPLICATION OF BACTERIOLOGICAL AND BIOCHEMICAL TESTS IN THE HYGIENIC JUDGEMENT OF MEAT AND MEAT PRODUCTS

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Public authorities in practically all the enlightened countries of the world have included meat hygiene in their programmes. What led them to take this step was the obvious necessity of establishing hygienic inspection in slaughterhouses so as to control the pathological conditions in animals slaughtered for human food.

This necessity became evident during the last decades of the nineteenth century, more especially because of the discoveries in parasitology showing how important parasites such as *Trichinella* and *Taenia* are transmitted to man, and the impact of large epidemics of so-called " meat poisoning ", the real cause of which began to be disclosed by the growing science of microbiology.

Organization of Hygienic Control of Meat and Meat Products

In many countries meat hygiene action is still limited to slaughterhouse inspection. Legislation and administrative practice do not take account of the fact that the hygienic control of meat cannot be confined to the slaughterhouses, but must also cover transport, storage, processing, and distribution of meat and meat products.

It is the practice simply to consider meat and meat products outside the slaughterhouse as one of a series of edible products coming under general food control. This control is either of a purely chemical nature, concerned with misrepresentations and adulterations, or a combination of chemical and sanitary control. Supervision of the service is in the hands of chemists, medical personnel, or sanitary engineers, and it depends upon the professional background of those responsible whether emphasis is placed on chemical composition standards, health control of food-handling personnel, or sanitary construction and maintenance of buildings

and premises. This system cannot, however, be regarded as meeting the hygienic requirements for meat control in countries with a developed meat industry.

Control of Foods of Animal Origin as a Special Branch of Food Control

Although, theoretically, any kind of food may deteriorate or acquire harmful qualities through contamination, infection, or development of toxic substances, practical experience has shown that meat and meat products (owing to their chemical and physical composition, which is classified as perishable) much more frequently present important problems of food hygiene. Both animal and vegetable products fall within the group of perishable foods. From the standpoint of food hygiene, however, perishable foods of animal origin (especially meat, poultry, fish, and milk, fresh and in the form of manufactured products) are the most important because of the role they play in the transmission of zoonotic diseases and because of the dangerous toxic microbiological processes they harbour. With the exception of the so-called high-protein, low-acid vegetables, which present microbiological problems similar to those of animal materials, the microbiological processes that take place in fruits and vegetables are of a harmless nature with respect to health. It is true that transmission of disease (amoebic dysentery and enteric infections) may take place through polluted vegetables and fruit. This, however, is not a problem of food inspection and control, but primarily one of sewage disposal and the prevention of faecal contamination of the soil.

A number of countries, with these considerations in mind, have developed the hygienic control of meat and milk into an expert service, drawn up on scientific and practical lines by veterinarians and the faculties of veterinary medicine.

A proper system of hygienic meat control will fall into two equally essential divisions: (*a*) control of slaughtering, and (*b*) control of meat and meat products during transport, storage, processing, and distribution. The two are technically inseparable and should be executed by personnel of the same profession (veterinarians) under one administrative authority.

Control in the slaughterhouse is primarily a matter of diagnosis, evaluation of pathological conditions in the animals, and supervision and enforcement of sanitary practices in slaughterhouse operations. Control of meat during transport, storage, processing, and distribution is primarily a matter of examination, evaluation of the hygienic quality of meat and meat products, and supervision and enforcement of sanitary practices in the handling of meat.

The knowledge upon which the exercise of modern hygienic meat control is based is derived from animal pathology, the epidemiology of zoonotic diseases, and the biology, chemistry, and microbiology of meat. In addition, a practical and theoretical knowledge of methods of meat preservation and processing is necessary, as well as of the hygienic and sanitary aspects of slaughterhouse operations and the meat industry. These various elements form the science of meat hygiene as taught at veterinary schools.

The methods used in practical control work are mainly organoleptic methods. When applied by skilled and experienced personnel they will in most cases solve the problems and provide an adequate basis for correct judgement, but a variety of laboratory methods—biological, biochemical, and bacteriological tests—are becoming increasingly important as a means of securing safer decisions in difficult cases, and also of revealing conditions that otherwise would remain undetected.

Access to a laboratory service is therefore essential to the organization of a modern and efficient system of hygienic meat control. In discussing these methods it is convenient to divide the subject into two parts—namely, techniques to be used in post-mortem inspection in slaughterhouses, and methods serving the inspection and control of meat and meat products outside the slaughterhouse.

Methods Employed in the Slaughterhouse

The main objective of these methods of examination is to diagnose in the animals pathological and other abnormal conditions that affect the wholesomeness and the hygienic quality of the meat. Some of the methods in this group, such as microscopical and histological examination of diseased tissues, are simply examples of the special application of ordinary diagnostic methods used in post-mortem techniques and histopathology. These need not be discussed specifically. It should be mentioned, however, that bacterioscopic examination of Ziehl-Neelsen stained slides from caseous processes in the submandibular lymph-glands of pigs has taken on considerable importance in recent years in Danish slaughterhouses and this is now a routine examination, serving to distinguish tuberculous processes in the submandibular lymph-glands from the necrotic foci produced by infection with *Corynebacterium equi*. The official Danish instructions for post-mortem examination and judgement of meat contain rules for this method of examination.

Other methods of examination are specific to meat hygiene. Most important within this group are bacteriological examination and determination of the pH of the meat.

Bacteriological examination

Bacteriological examination of animals suspected of infectious disease is a well-established practice in meat inspection in several continental European countries. Emanating from Germany, it has been widely used for many years. Technical procedures and the practical interpretation of the findings vary from country to country, however, and it is doubtful whether any attempt has ever been made to establish an international standard. If this could be done it would probably prove an incentive to the introduction of this method of examination in countries where it is now virtually unknown. The essentials of the regulations that are at present in force in Denmark, governing laboratory methods of examination and their application in the hygienic judgement of meat, are reproduced in Annex 14 (see page 447).

Bacteriological meat examination has been practised in Denmark since 1920, or earlier, and in 1932 it was recognized officially, having been incorporated in the Meat Inspection Rules of 21 July 1932. The new Meat Inspection Act of 1949 introduced revised rules that list a number of diseases and pathological conditions requiring a laboratory examination before judgement can be passed. The laboratory examination is extended to cover a bacteriological examination and determination of the pH of the meat as well. Detailed rules are given for sampling, technical procedures in the laboratory, and the interpretation of results.

The use of bacteriological methods in post-mortem inspection is based upon the theory that the internal organs and muscular and lymphatic tissues of healthy animals in a physiologically normal condition are sterile. If bacteria can be cultivated from these tissues, this indicates an abnormal condition.

Live animals carry micro-organisms on the skin and hair, and in the cavities of organs that communicate directly with the external surface through the natural openings, that is, the alimentary tract, the naso-pharyngeal cavities, and the external parts of the urogenital tract. In each one of these localities a characteristic, fixed natural flora of micro-organisms is found, consisting of species that are adapted to the different environmental conditions. Temporarily, of course, this natural flora may be mixed with other non-adapted species, derived from occasional contacts with contaminated materials.

All tissues and cavities that do not communicate directly with the external environment are sterile. There are no bacteria in the blood-stream, bone-marrow, lymph-glands, muscular tissues, and thoracic and abdominal cavities including lungs, liver, and spleen, provided the animals are healthy and in a physiologically normal condition.

Killing and dressing operations naturally change the bacteriological status. Sticking and bleeding in itself offers the opportunity for bacteria from the hide and the sticking knife to invade the sticking wound and the opened blood-vessels. The out-flow of blood tends to prevent bacteria from entering the blood-vessels and circulating through the blood-stream while the heart is still working; nevertheless, when methods of sticking are used that mainly open the jugular veins, reflex muscular contraction may temporarily close the sticking wound and thus allow blood to flow in its normal course towards the heart. As a matter of fact extensive research by Jensen and co-workers * on the microbiology of slaughter operations in Chicago packing-plants has shown beyond doubt that, in pigs, small numbers of bacteria originating from the sticking knife can be recovered regularly from bone-marrow and muscular tissues, when the carcasses are examined by elaborate culture techniques immediately after killing. It is also common experience that the clotted blood remaining in the heart of recently bled animals is nearly always found to be contaminated with bacteria, which must have been introduced by way of the sticking wound.

Therefore the sterile conditions prevailing in the blood and the tissues of healthy live animals are frequently lost at the outset, during sticking and bleeding. In practice, however, infection via the sticking wound is not very important under normal circumstances, because the number of bacteria introduced by this route is usually very small. It may, however, account for certain unexpected cases of spoilage developing from the bones (bone taint) in curing and pickling operations. This may be avoided if the precaution is taken of removing the bones and injecting pickle into the deeper layers of muscular tissue in hams and other cuts. For the purpose of bacteriological meat examination, infection through the sticking wound is normally negligible. It is still the general rule that the deeper layers of spleen, lymph-glands, and muscles of freshly-slaughtered healthy animals will prove sterile when examined by means of the ordinary techniques employed in bacteriological meat examination, although certain unexpected findings of low-grade non-specific infections by non-pathogenic bacteria attributable to the sticking wound cannot be excluded.

In removing the hide and opening the thoracic and abdominal cavities, the outer and inner surfaces of the carcass are, of course, exposed to contamination. The extent of this contamination depends upon the degree of cleanliness with which the dressing operations are performed (see also page 126). The sources of contamination are hide, intestinal contents, knives, cloths, water, and the handling workers. Thus, when dressing operations are completed, the exposed surfaces of organs and muscles, whether covered by subcutaneous tissue, fasciae, or serous membranes,

* Jensen, H. L. et al. (1942) *Food Res.* p. 273

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Live animals carry micro-organisms on the skin and hair, and in the cavities of organs that communicate directly with the external surface through the natural openings, that is, the alimentary tract, the naso-pharyngeal cavities, and the external parts of the urogenital tract. In each one of these localities a characteristic, fixed natural flora of micro-organisms is found, consisting of species that are adapted to the different environmental conditions. Temporarily, of course, this natural flora may be mixed with other non-adapted species, derived from occasional contacts with contaminated materials.

All tissues and cavities that do not communicate directly with the external environment are sterile. There are no bacteria in the blood-stream, bone-marrow, lymph-glands, muscular tissues, and thoracic and abdominal cavities including lungs, liver, and spleen, provided the animals are healthy and in a physiologically normal condition.

Killing and dressing operations naturally change the bacteriological status. Sticking and bleeding in itself offers the opportunity for bacteria from the hide and the sticking knife to invade the sticking wound and the opened blood-vessels. The out-flow of blood tends to prevent bacteria from entering the blood-vessels and circulating through the blood-stream while the heart is still working; nevertheless, when methods of sticking are used that mainly open the jugular veins, reflex muscular contraction may temporarily close the sticking wound and thus allow blood to flow in its normal course towards the heart. As a matter of fact extensive research by Jensen and co-workers * on the microbiology of slaughter operations in Chicago packing-plants has shown beyond doubt that, in pigs, small numbers of bacteria originating from the sticking knife can be recovered regularly from bone-marrow and muscular tissues, when the carcasses are examined by elaborate culture techniques immediately after killing. It is also common experience that the clotted blood remaining in the heart of recently bled animals is nearly always found to be contaminated with bacteria, which must have been introduced by way of the sticking wound.

Therefore the sterile conditions prevailing in the blood and the tissues of healthy live animals are frequently lost at the outset, during sticking and bleeding. In practice, however, infection via the sticking wound is not very important under normal circumstances, because the number of bacteria introduced by this route is usually very small. It may, however, account for certain unexpected cases of spoilage developing from the bones (bone taint) in curing and pickling operations. This may be avoided if the precaution is taken of removing the bones and injecting pickle into the deeper layers of muscular tissue in hams and other cuts. For the purpose of bacteriological meat examination, infection through the sticking wound is normally negligible. It is still the general rule that the deeper layers of spleen, lymph-glands, and muscles of freshly-slaughtered healthy animals will prove sterile when examined by means of the ordinary techniques employed in bacteriological meat examination, although certain unexpected findings of low-grade non-specific infections by non-pathogenic bacteria attributable to the sticking wound cannot be excluded.

In removing the hide and opening the thoracic and abdominal cavities, the outer and inner surfaces of the carcass are, of course, exposed to contamination. The extent of this contamination depends upon the degree of cleanliness with which the dressing operations are performed (see also page 126). The sources of contamination are hide, intestinal contents, knives, cloths, water, and the handling workers. Thus, when dressing operations are completed, the exposed surfaces of organs and muscles, whether covered by subcutaneous tissue, fasciae, or serous membranes,

* Jensen, H. L. et al. (1942) *Food Res.* p. 273

will carry a bacterial flora composed of species originating mainly from the skin flora and the intestinal flora of the animal. This, of course, makes it essential that samples for bacteriological examination be taken always from the deeper layers of the organs, glands, and muscles, by cutting through the surfaces with sterilized instruments after carefully cauterizing and discarding the superficial tissue. It also means that shipment of samples from the slaughterhouse to the laboratory involves a certain risk that bacteria from the superficial contaminating flora may invade the deeper tissues. This danger makes it preferable, wherever possible, to have the bacteriological examination performed in a laboratory on the slaughterhouse premises or situated close by. If shipment to some distant laboratory is unavoidable, proper handling of the samples is necessary. Any cut through the capsules or the natural surfaces must be avoided, and the samples must be cooled and wrapped individually in absorbent paper and then packed into non-airtight containers to prevent condensation of moisture. Shipment must follow by the speediest means available.

Bacteriological findings

The samples taken for bacteriological examination vary according to practices in different countries. It is, however, universally accepted that samples should include the spleen, lymph-glands of the carcass, and muscular tissue. Some investigators examine the liver and kidney as well. In accordance with theoretical concepts already expounded, the spleen, lymph-glands, and muscular tissues of healthy animals slaughtered in a physiologically normal condition are found free of bacteria. Theoretically the same should apply to the kidney. Experience, however, has shown that it is very difficult to prevent post-mortem bacterial invasion of the kidney tissues. Bacteria from the contaminated surface may very easily penetrate, via the opening of the pelvis through the tubuli into the renal tissue. Findings of non-pathogenic bacteria in the kidney removed from a slaughtered animal cannot, therefore, be considered as evidence of the intra-vital bacteriological status of that organ or of the carcass as a whole. A similar situation prevails in respect of the liver. The liver may be found sterile, but very often intestinal bacteria invade the organ via the vena portae, presumably both *intra vitam* and *post mortem*. Findings of bacteria in the liver can therefore be considered as significant only when the bacteria belong to recognized pathogenic species, such as *Salmonella*, *Listerella*, etc.

Bacteria found in bacteriological examinations of meat may be either specific, pathogenic bacteria or a mixed flora of non-pathogenic bacteria, resembling the natural intestinal flora. The presence of specific, pathogenic bacteria in the spleen, lymph-glands, or muscular tissue is easy to explain

as the result of a generalized septic or bacteraemic infection in the animal at the time of slaughter. The term " specific pathogenic bacteria " covers all species regarded as specific pathogens—namely, haemolytic streptococci, *Diplococcus lanceolatus*, haemolytic staphylococci, *Pasteurella*, *Salmonella*, *Escherichia* (in newborn animals), *Bacillus anthracis*, *Erysipelothrix*, *Listerella*, and *Corynebacterium pyogenes*.

It is harder to find a completely satisfactory explanation for the presence of non-pathogenic bacteria in the spleen, lymph-glands, or muscular tissue. Bacteria belonging to this group are species of non-pathogenic or potentially pathogenic bacteria, such as streptococci of the viridans group, enterococci, *Escherichia* (in full-grown animals), *Clostridium*, *Bacillus subtilis mesentericus* group, and non-haemolytic staphylococci. As will be noticed, these are species of bacteria that are present in the natural intestinal flora, some also appearing in the natural flora of the skin (non-haemolytic staphylococci).

It has been mentioned earlier that some instances may be explained as the result of an infection through the sticking wound, but in most cases the bacteria are apparently of intestinal origin. Although the mechanism is not well understood, it seems an established fact that a breakdown of natural resistance may, in some way or other, lead to an invasion into the tissues of bacteria from the intestinal tract or from other naturally infected cavities, that subsequently spreads through lymph- and blood-vessels and results in bacteraemia. This is prone to happen in animals that are slaughtered when in a poor or exhausted condition due to systemic disease or physical strain.

Interpretation of results

As there is no agreement on details of the technical procedure, it is not altogether surprising that interpretation and practical application of the findings also vary a great deal.

Sterile samples present no problem of course. It should, however, be remembered that the final judgement of the meat must always be left to the meat inspector. After receiving a negative answer from the laboratory, the meat inspector will have to inspect the carcass once again to reach his conclusion. Negative bacteriological findings will support a positive verdict, but there may be other than bacteriological reasons for condemnation. It must be clearly understood that bacteriological examination has certain obvious limitations and can never become a substitute for organoleptic inspection ; it is a supplementary measure only, to be used under specified conditions. It would be a technical error to apply bacteriological examination where non-infectious pathological conditions call for condemnation of a carcass.

Where specific, pathogenic bacteria are found in one or more samples, this should always lead to condemnation. A generalized septic or bacteraemic infection is a serious general condition affecting the hygienic quality of the meat in such a way that the carcass as a whole becomes unfit for human consumption, regardless of whether or not the bacteria are transmissible to man.

The interpretation of cases where only non-pathogenic bacteria are found is a matter of greater complexity. Must such findings necessarily lead to condemnation ? Admittedly the finding does not indicate that the animal is affected by a generalized infectious disease. The bacterial invasion of the blood-stream is a secondary development conditioned by some other pathological condition. It does, however, indicate that the animal was in an abnormal condition, and the spread of bacteria throughout the tissues greatly favours spoilage and bacterial decomposition, so that the keeping quality of the meat is impaired often to a very considerable extent. Rapid putrefaction may develop in the deeper layers of muscles, especially where clostridia are present, resembling the anaerobic putrefaction of dead carcasses and quite different from the normal course of bacterial spoilage of meat contaminated on the surface only. If the animal happens to carry *Salmonella* in its intestinal flora, the meat, when invaded by intestinal bacteria, may quite unexpectedly transmit salmonellosis. Inoculation of the meat with bacteria, some of which may be capable of producing toxins (*Clostridium perfringens*), also means an added risk of food poisoning of the enterotoxic type, whether the meat is used fresh or in manufactured products.

All aspects considered, condemnation seems justified when extensive infection of the carcass is established. According to the rules followed in Denmark, growth of non-pathogenic bacteria from more than one sample of any carcass (liver sample excepted) is considered evidence of a more extensive non-specific infection, and the judgement is condemnation. Growth of non-pathogenic bacteria from one sample only is not considered sufficient evidence of extensive non-specific infection. This result will be reported as a low-grade non-specific infection and is no hindrance to the passing of the carcass as fit for human consumption. The logic of this distinction may be open to discussion, more especially on whether it is correct simply to take the numerical count of the samples from which growth has been obtained as a criterion. Some investigators claim that non-specific infection found in muscle should be regarded as more significant than non-specific growth obtained from lymph-glands only.

pH determination

In the live animal the pH of muscular tissue is about 7.2 ; very soon after death a drop is observed. The reason for this is primarily a continuous

enzymatic breakdown of glycogen, which has been stored in the muscles, resulting in an accumulation of lactic acid. In live muscles the lactic acid content is only about 0.05%, whereas in muscles 24 hours after death as much as 0.5%-1% may be found. In three to six hours after death the pH drops to as little as 6.5 and within 12-18 hours it reaches its lowest level of about 5.6-5.8, with small variations. The rate of this process depends upon the temperature ; low temperature slows down the speed, but the extent and hence the range of change in the pH depends upon the amount of glycogen available in the muscles at the moment of death. In animals suffering from a febrile disease or exhaustion, deposits of glycogen in the muscles are low, because the maintenance of the normal glycogen content of muscle requires a normal intake of food, normal metabolism, and adequate rest. Starvation, excessive muscular activity, and the metabolic disturbances commonly following disease and physical strain will result in exhaustion of the organism's glycogen reserves. Consequently, in such circumstances, the pH will remain at a higher level. A pH well below 6.5 is unfavourable for bacterial growth, and hence meat in which normal amounts of lactic acid are formed will keep much better than meat in which the pH remains high, as a result of little or no lactic acid being formed.

System of Laboratory Examination in Operation in Denmark and Results Obtained

All laboratories engaged in the examination of meat must be approved by the State Veterinary Directorate, Division of Meat Inspection, which supervises their activity through monthly reports and inspection tours. About thirty larger slaughterhouses have their own laboratories. The remainder send their samples to one of the four central laboratories established in the larger districts. From the reports of these laboratories for the period March 1951 to March 1953, the following information on the functioning of the system has been compiled.

Bacteriological examinations (see also page 321)

Table I gives the total number of samples examined and the results obtained. The material is divided into two parts, one relating to the central laboratories and the other to the local laboratories, thus permitting of a comparison between samples examined after transportation and those examined locally.

The figures show that roughly 80% of the carcasses examined were sterile, 10% had non-specific infection in one sample only, 4% high-grade non-specific infection, and 6% specific infection with pathogenic bacteria.

TABLE I. BACTERIOLOGICAL EXAMINATIONS: MARCH 1951 TO MARCH 1953

	Total number of samples examined	Results			
		sterile (%)	low-grade non-specific infection (%)	high-grade non-specific infection (%)	specific infection (%)
Central laboratories	4 852	79.18	10.53	4.43	5.85
Local laboratories	4 974	74.85	11.82	4.48	8.84

The only significant difference between the two groups seems to be a somewhat higher percentage of specific infections found by the local laboratories. The reason for this, no doubt, is the positive interest shown by veterinarians who are doing both practical meat inspection and laboratory work. This enables them to accumulate personal experience in selecting for bacteriological examination those carcasses that are most likely to yield a growth of pathogenic bacteria. Again, this demonstrates that the closest possible relations between field and laboratory makes for the most efficient system of work.

A more detailed analysis of the material from one of the central laboratories shows a different picture when samples from pigs and from cattle are considered separately (see Table II).

TABLE II. BACTERIOLOGICAL EXAMINATIONS OF CATTLE AND PIGS: MARCH 1951 TO MARCH 1953

	Total number examined	Results			
		sterile (%)	low-grade non-specific infection (%)	high-grade non-specific infection (%)	specific infection (%)
Cattle	765	80	12.8	4.3	2.9
Pigs	258	62.4	16	8.5	13.2

A higher percentage of septic and bacteraemic infections was found among pigs than among cattle. In evaluating this finding it should be pointed out that, under cattle, the material comprised very few calves, as suspect young calves are normally condemned without laboratory examination, whereas the pigs were predominantly young animals (6-7 months of age).

Any post-mortem diagnosis is liable occasionally to reveal septic or bacteraemic infection (specific infection), but certain conditions are naturally more apt to produce general infections than others. The diagnoses that were most frequently found to be associated with laboratory findings of specific or high-grade non-specific infection are listed below, in order of priority:

Cattle	*Pigs*
Osteomyelitis	Osteomyelitis
Delivery complications	Peritonitis
Enteritis	Endocarditis
Metritis, tendovaginitis, abscesses	Prolapsus uteri
Wound infection	Arthritis, tendovaginitis, abscesses
Prolapsus uteri	Metritis
Diagnosis uncertain, suspected of sepsis	Ruptura uteri
	Enteritis
	Diagnosis uncertain, suspected of sepsis
	Delivery complications
	Wound infection

The complete list of pathological conditions in which the Danish Meat Inspection Rules, under certain criteria, make laboratory examination compulsory is as follows:

All emergency-slaughter cases
All animals showing fever or symptoms of acute disease, or both
Endocarditis verrucosa
Pneumonia (certain forms)
Gastro-enteritis catarrhalis acuta (in adults)
Peritonitis (local)
Pyometra and chronic or sub-acute endometritis
Retentio secundinarum
Delivery complications
Prolapsus uteri and ruptura uteri
Mastitis purulenta
Infectious arthritis or tendovaginitis
Wound infection
Osteomyelitis
Burns

pH determinations

The results of the pH determinations carried out on the above-mentioned material from one of the central laboratories are given in the following tabulation:

	Total number examined	*pH of muscle above 6.5*	
		number	*percentage*
Cattle	765	44	5.8
Pigs	258	55	21.3

An abnormally high pH was found to be associated most frequently with peritonitis, enteritis, delivery complications, arthritis, and cases of uncertain diagnosis suspected of sepsis. In 21 cases out of 99, the abnormally high pH values of the muscles were found to coincide with specific infection or high-grade non-specific infection ; in 78 cases, the bacteriological examination was negative.

Methods Employed outside the Slaughterhouse

The hygienic control of meat and meat products during transport, storage, processing, and distribution offers a wide field for the application of laboratory methods of examination. In the past, however, especially in countries where control is merely a part of the general food measures and not of the specialized veterinary meat control, very little use has been made of the laboratory within this field. As pointed out before, medical personnel and sanitary engineers have concentrated their efforts in food control work upon health control of food-handling personnel and sanitary construction and maintenance of premises. Very little attention has been paid to the examination and judgement of the food products themselves, particularly with respect to hygienic standards and quality. Some chemical analyses of manufactured meat products may have been carried out, but there is no doubt that ordinary chemical analysis, as employed in general food-control work, gives very limited information on the quality of a foodstuff prepared from complex natural products such as animal raw materials. After all, the quality of a sausage, for instance, is determined by many more essential factors than simple quantitative chemical data. The kind and quality of meat and the process of manufacture are decisive factors that cannot be estimated in a chemical laboratory.

While health control of employees under certain circumstances may be of consequence, and control of sanitation certainly is important, it seems obvious that hygienic examination of the product itself is indispensable as the only means of determining deficiencies in hygienic quality, and of finding ways for correcting such deficiencies and improving the general hygienic standards of the product. Where such examination is lacking, the controlling authorities are left in complete ignorance as to the hygienic quality of the foods and are not in a position to pass correct judgement on suspected consignments.

In the examination of meat products for hygienic quality, skilful organoleptic examination, based upon a thorough knowledge of the raw materials and of methods of conservation and processing, must be accompanied by bacteriological and biological laboratory testing.

A list of the most important laboratory techniques for this purpose includes the following groups :

1. Biochemical tests to determine deterioration of fats and fatty tissues (oxidation, rancidity) : titration of free fatty acids ; peroxide number ; stability tests ; Kreis' reaction.

2. Bacteriological tests for examination of canned products : incubation test ; aerobic and anaerobic bacteriological analysis.

3. Bacteriological and biochemical tests to determine state of freshness of meat and meat products : quantitative and qualitative bacteriological analysis ; reduction tests ; pH determination ; hydrogen sulfide tests ; etc.

4. Examinations of pickle and determination of salt and water in salted products to estimate keeping quality : catalase tests ; pH determination ; bacteriological analysis ; titration of chloride ; determination of water content.

5. General bacteriological analysis (clostridia, coliform bacilli, potential food-poisoning organisms such as staphylococci, *Bacillus cereus*, and salmonellae). Bacterial counts and bacteriological standards.

Microbiology of Meat

The natural bacterial flora of freshly slaughtered meat consists of the following principal genera :

Achromobacter	*Proteus*
Micrococcus	*Streptococcus faecalis*
Flavobacterium	*Thermobacterium*
Pseudomonas	*Bacillus*
Aerobacter	*Clostridium*

During storage, handling, and processing, the varying environmental conditions will change the qualitative and quantitative composition of the bacterial flora. Continuous contamination during operations and admixture of ingredients such as milk, milk-powder, and flour may add new species to the original flora ; for instance, staphylococci and Enterobacteriaceae from the former source, and lactic acid bacteria, *Bacillus* sp., and clostridia from the latter. Low temperatures (cold storage), salt, and heating all exercise a selective effect. Cold storage promotes the frigophilic species such as *Achromobacter*, *Pseudomonas*, certain types of *Micrococcus*, and *Aerobacter*, and these will soon outnumber the mesophilic and thermophilic species. Salt has a strong inhibiting effect upon most bacteria, except the salt-tolerant species of *Achromobacter* and *Micrococcus*. Heating brings about a complete change of the bacterial flora, spores and thermoresistant streptococci and *Thermobacterium* alone surviving.

In freshly slaughtered meat the bacterial count is usually fairly low, but in meat products, which are generally made from meat that has been stored for some time, the bacterial count is very often high, even extremely high. Because of the large and varying quantities of micro-organisms on stored meat, simple bacterial counts of meat products ordinarily bear little or no relation to standards of hygiene during the manufacturing process (see Annex 12). In raw non-salted meat products there is a correlation between bacterial count and keeping quality, because the microbiological processes can develop freely, whereas in raw salted products no such correlation can be expected. The salt and other curing chemicals will interfere with the growth and enzymatic activities of the bacteria, and the salt-tolerant species of bacteria that may develop are usually biochemically inactive towards proteins and other components of the meat.

In cooked or baked meat products, submitted to some low-temperature process comparable in its effect to pasteurization, bacterial counts and bacteriological standards may no doubt prove useful. Excessive numbers of non-thermoresistant organisms found in this type of product, which should normally contain only thermoresistant and spore-bearing bacteria, means that the product has been exposed to recontamination after heating, and stored at an unsuitably high temperature. Both these conditions are perfect for the development of food-poisoning bacteria, where the appropriate type of organism happens to be present.

For cooked or baked, non-salted or slightly salted meat products a fairly good correlation between the bacterial count and the keeping quality or state of freshness is also to be expected.

Bacteriological techniques

Because of the varying conditions and objectives of the bacteriological examination of meat products, it is not easy to devise a simple standard technique that will be satisfactory in all cases and that will replace personal experience.

Microscopic examination of direct smears is very often extremely useful for estimating numbers and types of micro-organisms, and provides valuable guidance in selecting the proper cultural procedures.

For a simple bacterial count, to plate diluted suspensions of the material in ordinary meat-infusion/peptone-agar is satisfactory, but, in addition, the material should always be plated in blood-agar. The latter medium gives a direct indication of potential food-poisoning organisms such as *Staphylococcus aureus* and *Bacillus cereus*, as well as ready information on *Streptococcus viridans* and *Enterococcus*, as a result of the characteristic haemolytic effects shown by all these organisms. For the detection of Enterobacteriaceae (*Escherichia*, *Salmonella*, and *Shigella*) several well

known procedures are available (see Annex 11). Frigophilic and salt-tolerant bacteria can be cultivated by means of low-temperature incubation or media containing high percentages of sodium chloride. For a simple technique to estimate the number and types of clostridia there is probably no better method than the use of Riemann's modification of the Crossley milk/fishmeat/peptone/bromocresol-purple medium (see Annex 12).

Organization of laboratory service

The chemist engaged in analysis of foods for chemical composition is usually able to follow well-defined standard methods ; he will be able to do efficient laboratory work and establish quantitative and qualitative chemical data on a product without having any closer contact with or knowledge of the practical field whence his sample is drawn. Interpretation and practical application of the findings of a chemical analysis for composition standards, misrepresentation, or adulteration rarely give rise to difficulties, and inspectors and others working in the production field will generally be able to utilize the data without having any particular knowledge of laboratory work.

The matter is altogether different when it comes to the application of bacteriological and biological methods of laboratory examination in the evaluation of the hygienic quality of food products.

It is the exception for the laboratory worker in this case to be able to follow well-defined standard methods. His choice often depends upon an intimate knowledge of the particular product and of special and general production conditions. Again, the practical application of the results of such examinations often presents difficulties which can be overcome only if the inspectors and others working in the production field have sufficient knowledge to be able to utilize—in an intelligent and useful way—the opportunities afforded by laboratory assistance. The mere statement of findings has no intrinsic value. What matters is that action should be taken to correct the situation brought to light, to fight undesirable types of bacteria, to improve the general hygienic standards of production, and to prevent spoilage. Obviously, this cannot be achieved merely by quoting figures from a laboratory report. Teamwork between laboratory and field workers is generally the only way to tackle the problem of tracing sources of bacterial contamination or localizing faulty procedures in the handling and processing of foods.

In short, certain elements of chemical food control can be carried out by field workers who know nothing about laboratory work, and by laboratory workers who know nothing about field work—two separate spheres working together through the receiving desk and mail office of the laboratory. But hygienic food control most certainly cannot. There is ample

evidence to this effect in countries that have tried the system. Hygienic and bacteriological laboratory examination of food has never developed into a really practical and useful service, but has remained always at a rudimentary stage.

If laboratory methods are to be utilized in the hygienic control of foods of animal origin—as is essential in the interests of public health—the closest possible co-ordination and co-operation must be instituted between the laboratories and the field staff. This will require a considerable decentralization of laboratory work; laboratories will have to be located in the field, and field staff attached to them as the centre of activity.

An example of this type of organization that has been working for well over 30 years is found in the veterinary milk-control system in Denmark.

Part V

PROCESSING AND MARKETING

HYGIENIC ASPECTS OF MEAT PROCESSING

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Condition of Slaughter Animals with Reference to Meat Quality

It is well known that the condition of the animals and the treatment they receive before slaughter have a decisive influence on the quality and keeping properties of meat products—particularly in the case of pigs. This is especially true of canned sausages and ham, either raw or cooked. Careful selection and care of the animals to be slaughtered is therefore essential. The most suitable animals are young, of average fatness, and in perfect condition. The meat of older animals, or of animals which are skinny or over-fat, is less suitable. For the successful preservation of meat, i.e., to obtain meat that will lend itself to long storage and transport, it is essential to ensure that animals are in a completely rested condition at the moment of slaughter. The flesh of animals slaughtered after a long journey often contains a large number of bacteria, and the risk of easy decomposition is thus created, particularly on account of the obligate anaerobes.

It should be remembered that the state of the animal before slaughter to a great extent determines the degree of rigor mortis as well as of the acidification and maturation of the meat. The facility with which the meat absorbs the pickling substances depends, in its turn, very largely on the proper maturation of the meat after slaughter. The electrical resistance of the muscles immediately after slaughter—which is in direct relation to the state of rest or fatigue of the animal—is extremely important for the preservation of the meat. It is no accident that the keeping quality is often higher in the case of animals slaughtered on the farm than it is when slaughter takes place in the abattoir. Another point of importance is that the high degree of electrical resistance found in meat from unrested animals is regularly accompanied by an increase in the pH. In abattoir pens it is essential to ensure that animals—in particular pigs—are given conditions that enable them to become really calm before slaughter. In order to be comfortable, the animals must feel well fed. The meat of hungry animals is not suitable for the manufacture of preserved meat products for consumption at a much later date, since lack of glycogen in the muscles means

insufficient acidification and the meat does not mature. The feeding of the animals should cease eight hours before the time fixed for slaughter, so as to prevent the penetration of bacteria from the intestines into the blood and flesh via the lymphatic system. It is not necessary to discuss in detail here the practice of administering to pigs, shortly before slaughter, fodder rich in carbohydrates, since it is generally known that such foods increase the muscle glycogen and consequently favour the formation of lactic acid. It is also common knowledge that such meat is especially suitable for preservation and that it has a particularly good flavour. But, above all, the formation of lactic acid increases the keeping properties of meat. A neutral or slightly alkaline reaction (pH, 7-7.4) creates the best conditions for the growth of putrefying agents. The formation in the meat of a sufficient quantity of lactic acid, with a pH of 5.6-6.2, is of the greatest importance for the inhibition of any putrefactive bacteria which may be present. In addition, it should be mentioned that the inhibitory and lethal action of the nitrite in a nitrite-containing pickling-agent on bacteria—particularly on anaerobes which so often cause the decomposition of preserved meats—is considerably strengthened by a reduction in the pH of the meat. It is known that the nitrites have an inhibiting effect even at a concentration of 0.05%, and that this effect is considerably strengthened when the meat pH is 6.0 or less. This again emphasizes the fact that subsequent changes in the meat depend very largely on the condition of the animal at the moment of slaughter.

Great importance must be attached to rigor mortis as a criterion by which the quality of meat may be judged, and here it must be remembered that if rigor mortis develops too rapidly, taking the form of cramp (for example, in cattle and pigs, shortly after slaughter), it is always a sign that the meat of the animal will not keep well and that it is not suitable for the preparation of good preserved meat. Compared with rested muscles, the muscles of an exhausted animal are poor in oxygen and, consequently, do not supply the necessary energy for adenosine triphosphoric acid resynthesis. It is to be expected that muscles which are poor in carbohydrates—as the muscles of animals exhausted in transit very often are—will not give complete rigor mortis, since the breakdown of the adenosine triphosphoric acid (which is necessary for the contraction of the muscles) cannot take place in a normal manner in the absence of hexoses.

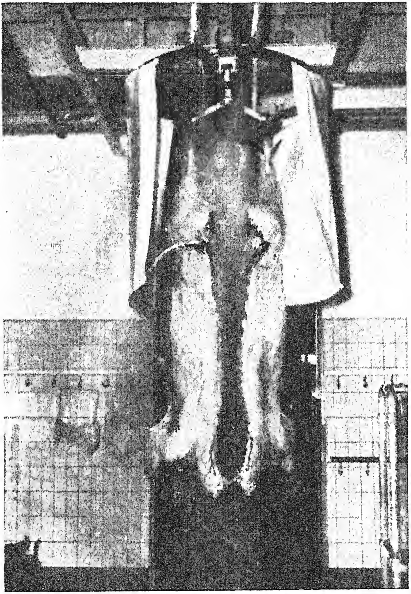
Stunning and Slaughter

The method of stunning also plays a considerable role in obtaining meat which will keep well, and particularly in avoiding muscular bleeding (see also pages 137, 147). It might be advisable gradually to discontinue the practice of stunning by electric shock or by the captive-bolt pistol,

and to substitute for these the method, increasingly adopted in the USA, of rendering pigs unconscious by means of carbon dioxide. The advantages of this method are the following:

(1) it does not excite or tire the animal and this has a favourable effect on the quality of the meat;

FIG. 1. WASHING OF BOVINE CARCASS BY HIGH-PRESSURE WATER JETS



Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

(2) it renders bleeding easy, since the animal remains motionless after being made unconscious by the carbon dioxide and the necessary incisions can therefore be made with precision;

(3) the carbon dioxide intensifies respiration and thus favours circulation and, consequently, bleeding;

(4) it prevents muscular bleeding and too great a change in the pH due to muscular cramps when the animal is stunned;

(5) it renders the whole operation of slaughter more humane.

Immediately after stunning and bleeding, skinning should take place. Pigs should be scalded, cleaned, and depilated by immersion in a very hot resinous substance, in such a manner as to avoid any contamination of cutaneous or subcutaneous tissue.

During recent investigations concerning the study of food products at the Institut für Lebensmittelkunde und Milch Hygiene, which is attached to the Tierärztliche Hochschule, Hanover, it was found that the water in the scalding vat was an important factor in the contamination of the surface of the pig's flesh with sporogenic aerobes. Those responsible for equipping the abattoirs should find some device for scalding pigs while suspended from a rail, by spraying them from vertical rows of nozzles so that the water will run downwards from the hind quarters to the head. These depilation sprays should be constructed so that steam can be applied at the same time, thus loosening the bristles and removing dirt from the skin as rapidly as possible. However, so long as many countries still lack such installations it is essential to insist—particularly when pigs are slaughtered for export—that the scalding water be changed as often as possible and that, after use, the vats be freed from bacilli and spores as completely as possible.

In many countries it is the usual practice to wash down not only the carcasses of pigs, but also the split carcasses of oxen, by means of high-pressure water jets (see Fig. 1). The cloths previously used for washing the carcasses have everywhere disappeared, since it was recognized that they were a source of contamination. The method of covering the two halves of the ox with cloths soaked in 10% saline solution has been found extremely satisfactory in the USA.

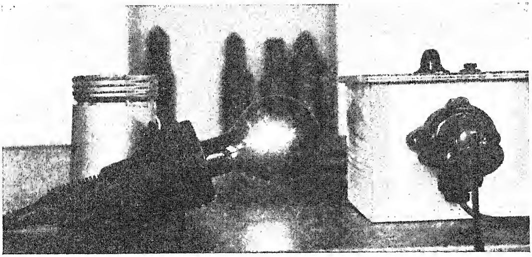
Storage and Refrigeration of Meat

The clean halves of the carcass should then be sent to the cold rooms for thorough refrigeration. At the present time the temperature of chambers in which meat is refrigerated or subjected to preliminary refrigeration is kept at a uniform 0°C (32°F), and chilling is continued until the temperature inside the meat does not exceed 3°C (37.4°F). As far as possible, the relative humidity is kept at 90% when freshly slaughtered animals are put into cold storage, rising subsequently to 95%. In order to obtain

rapid desiccation of the surface, the humidity should be maintained at 80%-85% at the beginning of refrigeration. The air circulation per hour should be 10 to 15 times the volume of the chamber, and the air in the interior of the chamber should be completely changed five or six times per day. In cold chambers for the storage of meat for fairly rapid consumption, the temperature is uniformly fixed at from 0°C to not more than 1°C (33.8°F) throughout the world. In such chambers the relative humidity is 80%—90%, and the circulation of air per hour is six to eight times the volume of the chamber; the air should be completely changed two to four times per day.

The bacterial content of the air in the cold chamber is a factor of special significance for the keeping properties of meat during refrigeration and cold storage. It should be noted in this connexion that the air of the cold chamber contains not only non-sporogenic bacteria of the mesophilic group, such as the coliform bacteria, but also sporogenic aerobes, moulds, yeasts, and other psychrophilic organisms—in particular those belonging to the fluorescent group. Experiments have clearly shown that even constant cleaning and disinfection of cold chambers does not reduce the number of spores contained in the air of such premises, nor prevent the presence of spores on the walls and ceilings. It should be noted that the disinfectants most in use at the present time—whether hypochlorites, quaternary ammonium compounds ("Quats"), or ampholytic soaps ("Tego 51", for example)—do not destroy the spores of aerobes and anaerobes in sufficient quantity. To destroy them or inhibit their growth

FIG. 2. ULTRA-VIOLET LAMP * FOR INSPECTION OF SAUSAGES AND SAUSAGE-MEAT



* High-pressure mercury discharge lamp (Philips' HPW lamp)

Left : rubber lamp-holder *Behind : lamp casing* *Right : switch*

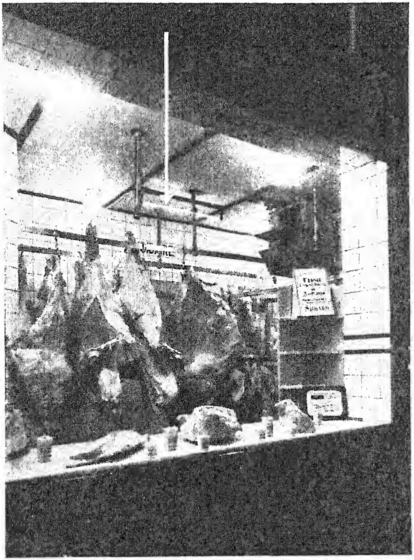
FIG. 3. USE OF ULTRA-VIOLET LAMP * FOR SURFACE STERILIZATION OF HAMS

* Hanau Quartz Lamp Co.

the additional use of ultra-violet-ray sterilization lamps is to be recommended (see Fig. 2, 3). But in this connexion it should be emphasized that in cold chambers, where the temperature is normally 0°C, ultra-violet-ray sterilization lamps as usually employed (irradiation of 254 mμ) have little or no bactericidal effect (see Fig. 4, 5). This is due to the fact that temperatures around 0°C prevent the evaporation of the mercury, which is absolutely essential in the low-pressure mercury-vapour lamps nowadays in general use for this purpose. The intensity of radiation from

these lamps is very slight and, consequently, their inhibitory action on the bacteria is also only slight. However, sterilization lamps have been produced which are specially suitable for use in cold chambers, and whose power is 14 μW per cm^2, at a temperature of 20°C (68°F). and

FIG. 4. ULTRA-VIOLET BACTERICIDAL LAMP IN COLD-STORAGE ROOM



22 μW per cm^2 at 0°C. The sterilization lamps in general use today in cold chambers do not generate ozone.[4] It should be emphasized that the use of highly efficient disinfectants such as "Quats" or ampholytic soaps, combined with a suitable method of sterilization by ultra-violet rays, is the best way of reducing the number of bacteria in the air and on the walls and ceilings of cold chambers. Further investigations are necessary to ascertain whether cold chambers can be adequately disinfected by aerosols—for example, triethylene glycol vapour or spray—and whether this method is practicable.

FIG. 5. MOBILE ULTRA-VIOLET BACTERICIDAL LAMP *
IN COLD-STORAGE ROOM

* Philips

Water Content of Meat

Advanced studies have been made at the Institut für Lebensmittelkunde und Milch Hygiene of the causes of failure in the manufacture of meat products for preservation over long periods. It has often been found that an essential and decisive factor is the water content of the meat. A clear distinction must here be made between the total water content of the muscles and the quantity of water liberated when the muscles are cut, that is, the liquid spontaneously expelled from the meat. Thorough research has made it possible to establish the fact that there are pigs whose meat has a 72%-75% water content but from which no water is liberated by cutting because the liquid is retained in the muscle tissues. On the other hand, it was found that pork which was particularly wet when it was cut up, with a total water content of 68%-72%, gave off large quantities of the water. Such meat is described as having a high free-water content, and it might be desirable to examine and clarify this concept. Experience has shown that the free-water content of meat is an important factor in the great multiplication of micro-organisms which cause decomposition, especially when the meat is cut up into small pieces. In German meat-product industries it has been found useful to keep the free-water content as low as possible during the preparation of meat products. A procedure

has therefore been adopted by which beef or pork with a high water content is allowed to drain and dry. According to experiments so far made, the best method seems to be to use flat refrigerator baskets for this purpose. The meat, roughly cut up, is placed in these trellis-baskets and left in the refrigerator chamber for one night so that the free water can drain off without difficulty.

Obviously, neither the butcher nor the meat-product industry can in all cases establish by means of chemical investigation a water content that varies between 55% and 75%. Some method has to be found, therefore, of arriving at an approximate estimate of the water content. For this purpose, the use of a plexiglass compressor is recommended. The method consists in placing a small piece of muscle (0.5 g) between the plexiglass plaques of the compressor, and slowly and regularly tightening the screws to the maximum. In the case of pork or beef in perfect condition for the manufacture of first-class meat products, one of two results will be obtained : either the piece of muscle compressed in this way will give off no water at all, or a thin halo of water will form round the piece of meat. When the meat has a high water content (and is therefore not suitable for the manufacture of meat products) the water halo will extend for several millimetres around the piece of muscle, and drops may even ooze from between the plexiglass plaques. The German Federal Institute for Meat Research has gone a step further by passing a piece of strongly hydrophilized white blotting-paper under the lower plexiglass plaque in order to show more clearly the quantity of water liberated from the meat.

Bacterial Contamination of Meat and Meat Products

Clean slaughtering, with the resulting relative absence of microorganisms on the surface of the meat, is a decisive element in the successful manufacture of high-quality meat products. Recently, careful research has repeatedly shown that, besides the aerobes which usually act as putrefying agents (e.g., the Gram-positive *micrococci*, the coliform bacteria, the fluorescents, and the achromobacters), sporogenic aerobes of the types listed below can have an influence on the meat and especially on meat products :

(1) *B. mesentericus*, with its numerous varieties ;
(2) *B. subtilis*, in its various forms ;
(3) *B. mycoides ;*
(4) *B. megatherium ;*
(5) *B. cereus.*

These bacilli belong to the group of albumin-decomposing agents; they can even create very strong proteolytic fermentation, and their role is important in that they can bring about failure in the manufacture of meat

products, especially preserved ham, meat, and sausages. Special attention should be drawn to the fact that the proteolytic decomposition caused by these bacilli may, on particularly favourable material, give rise to the decomposition products of muscle protein such as toxic amines (muscarine, for example). This is true particularly of bacilli of the *mesentericus-subtilis* and *cereus* groups.[1, 2, 3]

During recent years, my attention has been specially directed to difficulties in the production of sausages. Here, failures are due essentially to mistakes made in the drying process, when the sausages are hung up in an environment where the temperature is too high—above 15°C (59°F)—and the humidity too low (less than 80%). Under these conditions a dry zone of 2-5 mm forms under the skin of saveloys, salami, and the various types of *Mettwurst*. This dry, surrounding layer prevents the drying-up of the interior of the sausages which is so important for preservation of their quality; the drying should take place from the inside outwards. Bacteriological examination has shown that in 70% of cases where raw sausages were a failure owing to this faulty drying, large numbers of bacilli of the *mesentericus-subtilis* group were present, particularly those in the dry and the mucilaginous form—that is, *B. mesentericus viscosus*. It has been noted that during this process of disintegration the sausages at first acquire a slightly sharp flavour, dependent on the rate of multiplication of the *mesentericus-subtilis* bacilli, and are more acid; when the multiplication is very great, real decomposition of the meat albumin takes place, accompanied by the musty smell typical of putrefaction caused by *mesentericus*.

Furthermore, cooked hams for export are extremely liable in preparation to the ravages of bacilli of the *mesentericus-subtilis* group. There is no doubt that the *mesentericus* spores which survive the usual cooking at 85°C (185°F) or rapid cooking at 100°C (212°F) and gradually develop (particularly when tinned ham is kept in a warm place), cause disintegration of the ham, generally without any formation of gas. Such ham then has a musty, sharp, and doubtful flavour.

In order to avoid the infection of meat products intended for preservation over long periods, it is essential always to insist on absolutely clean slaughtering and on high standards of hygiene in manufacturing premises, especially in pickling rooms.

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DISPOSAL AND RECLAMATION OF BY-PRODUCTS

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It is, of course, the first task of the meat inspector to try to secure that meat offered for sale originates from animals which were in a sound and healthy condition when slaughtered. This is done by the ante- and post-mortem veterinary inspection of slaughter animals and the condemnation of all meat unfit for human consumption. The meat inspector has furthermore, however, to ensure that sound meat does not become contaminated or infected by direct or indirect contact with the condemned meat in the slaughterhouse. To operate a slaughterhouse in a hygienic way, it must be required that the condemned meat be collected immediately after inspection and brought to a separate room at the slaughterhouse. It is, of course, necessary to get rid of the condemned meat and offal which is unfit for human consumption. A simple way might be to spread it out in the fields surrounding the slaughterhouse, but in this way infections and parasitic diseases spread to other animals or perhaps human beings, flies breed, and odours are caused. To avoid this, animal remains should be handled in such a way that all infective material is sterilized or reduced to an otherwise inoffensive non-infective state.

Methods of treatment

The methods used most commonly for hygienic disposal of meat confiscated from slaughterhouses are simple incineration, chemical treatment, and thermal treatment (or dry rendering).

Incineration is, no doubt, a sure method but at the same time the most unsuitable economically, as it requires the consumption of much fuel and does not result in a useful product. However, where only small quantities are concerned, it may be too expensive to bring the material to a plant for chemical or thermal treatment, and incineration is to be preferred. Sometimes burying is recommended for the disposal of small quantities, but this may set up areas of latent infection of, for example, anthrax.

Both chemical and thermal treatment require the installation of rather expensive machinery, but have proved profitable methods ; the final products of such processing are " technical " fat, and meat- and bone-meal.

It may be of value to describe briefly the process in a destruction plant; as thermal treatment is the most common method used, it may be taken as an example.

After the animal has been skinned, the raw material (dead animals, condemned carcasses, and offal) are cut into pieces of suitable size. If there is much bone, it is necessary to have a bone-crusher on the receiving-floor, which is always sited above the room for the sterilization machine or dry-render. There, the material is loaded into the render through the charging-hopper and this is securely closed. The dry-render is a horizontal, steam-jacketed cylinder, fitted with a powerful central agitator shaft (see Fig. 1, 2). When it has been loaded, pressure is raised in the steam-jacket. As the material comes into contact with the heated surface of the inner cylinder, while being agitated, its moisture is converted into steam, which creates an internal steam-pressure according to the pressure of the steam-jacket, which must be high enough to cause disintegration and sterilization of the material. After the internal pressure has been released, the process is continued until the final products are dry; they are then discharged by the central agitator shaft into a receiving tank from which the free fat drains away. The solids called " greaves " or " cracklings ", which still contain up to 20% fat, are then treated in order to remove the fat. This

FIG. 1. DRY-RENDER AND RECEIVING TANK

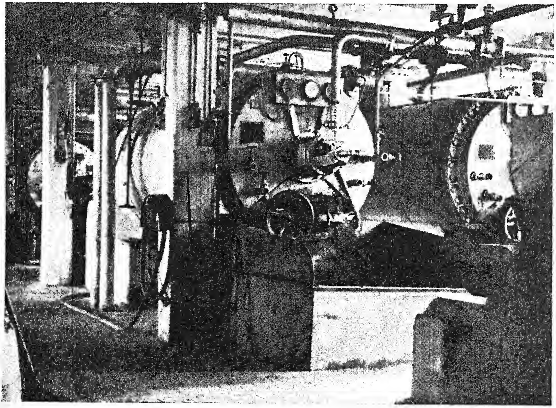
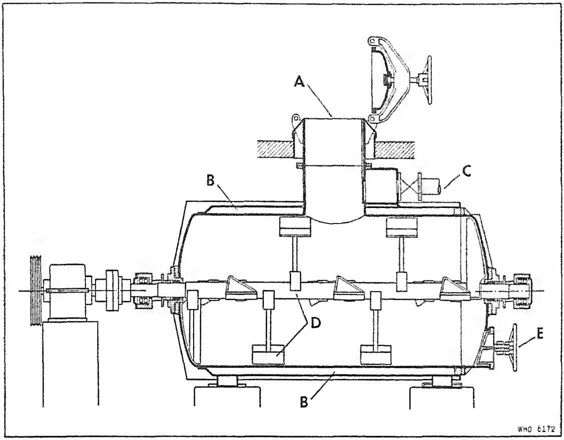


FIG. 2. SCHEMA OF DRY-RENDER



A *Charging-hopper*
B *Steam-jacket*
C *Exhaust valve for inner cylinder*
D *Agitator shaft*
E *Discharge valve*

is usually done either in a hydraulic press (see Fig. 3) in which the greaves are pressed in thin layers, or in a steam centrifuge. By either of these methods there still remains between 8% and 10% of fat in the end-products and, since fat generally has a higher price than meat- or bone-meal, it is essential for the economy of the process to extract more fat from the greaves. It has therefore become more and more common during recent years to extract the fat from the greaves with petrol, either in special extraction plants or in a petrol centrifuge (see Fig. 4). In this way it is possible to bring the fat content of the end-products down to 1% or even lower. The rest has then to be disintegrated (see Fig. 5), ground, and sacked as bone- and meat-meal, which is done in the " millery ". The fat is refined and sold as a technical grade.

There are a few plants in Denmark for chemical treatment ; two for direct fat extraction from bones with hot (90°C) petrol vapour, and one as a mixed method—steam sterilization, following extraction with trichlorethylene. The latter plant is used for all kinds of raw materials.

FIG. 3. HYDRAULIC PRESS FOR EXTRACTION OF FAT FROM GREAVES

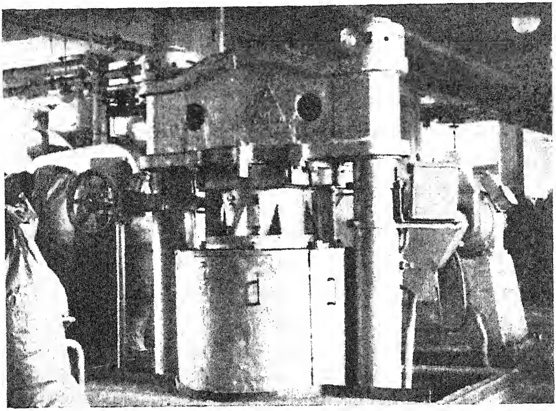


FIG. 4. PETROL CENTRIFUGE FOR EXTRACTION OF FAT FROM GREAVES

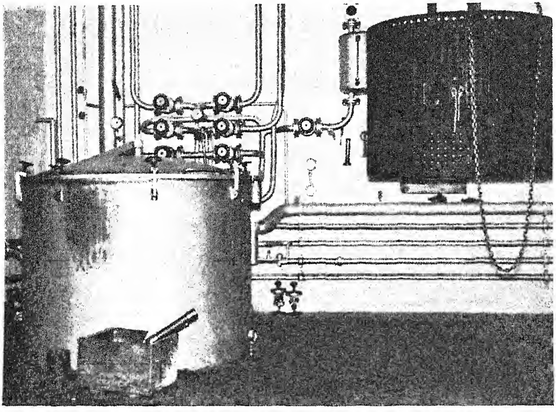
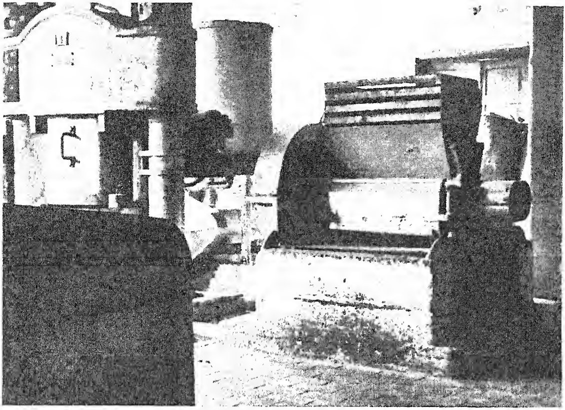


FIG. 5. MEAT- AND BONE-MEAL CRUSHER



The meal is crushed after pressing and before grinding.

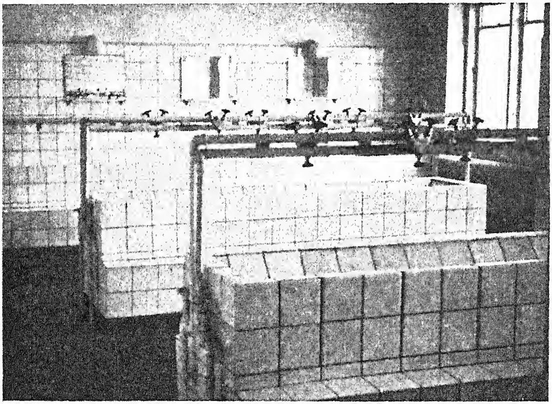
Lay-out of plant

From a hygienic point of view it is essential that the collecting and handling of the material take place in such a way that infection of other material, animals, or human beings, is avoided. It is therefore to be preferred that the collection from the slaughterhouse be done by special trucks and workers belonging to the destruction plants. As one of the end-products of the treatment is bone- and meat-meal, which is used as animal fodder, it is, of course, of the greatest importance that the destruction plant is built and run in such a way that there will be no direct or indirect contact between the infected raw materials and the end-products. It should thus be strictly divided into two departments: the " unclean " department, where infective materials are brought in, and the " clean " department, where sterilized materials are treated and stored.

The " unclean " department consists of unloading platform, room for skinning and cutting up of dead animals, room for salting and storing of hides, cloakrooms, wash-rooms, and dining-room for the personnel engaged there and for the drivers of the trucks collecting offal and dead animals. There must be no admittance to this department except for the drivers and workers and, in special cases, engineers, and the head of the destruction

plant. Special precautions must, of course, be taken to prevent animals and birds from entering. The floors and walls of the " unclean " department must be easy to clean and disinfect—i.e., they should be covered with smooth concrete or tiles. As personal hygiene is very important, opportunity must be given to the workers to wash and change clothes before they leave the plant when the work is finished (see Fig. 6, 7). It is thus necessary to have the cloakrooms divided into one for working-clothes and another for home-going clothes, with, between them, a wash-room with showers, and both cold and hot water. It is essential that there be such separate service rooms for the " unclean " and " clean " departments.

FIG. 6. WASH-ROOM OF DESTRUCTION PLANT

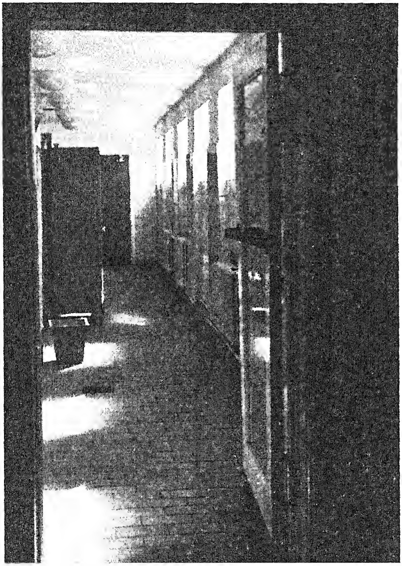


The room for salting and storing of hides must be easy to clean and disinfect ; the floor and walls should be tile-covered and sewerage for waste water should be provided. To diminish the danger of infection, it will be necessary to keep the hides in salted condition for some time—generally at least 14 days—at the destruction plant before delivery to a tannery.

The transport of materials (condemned meat, offal, and dead animals) must be carried out by trucks belonging to the destruction plant and

equipped in such a way that they are easy to clean and disinfect. The bottom of the trucks must be waterproof to prevent infective material or liquid from leaking out during transport.

FIG. 7. CLOAKROOM OF DESTRUCTION PLANT



The "clean" department consists of a room for the sterilization-machinery, the hydraulic press, and/or the centrifuge, a "millery", a refinery for fat, rooms for storage of meat- and bone-meal and technical fat, and cloakrooms, wash-room and dining-room for the personnel. The floors and walls of these rooms must be easy to clean and disinfect, and should therefore be covered with smooth concrete or tiles.

The autoclave for sterilization of manure and waste water is also connected with the "clean" department.

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FIG. 6. WASH-ROOM OF DESTRUCTION PLANT

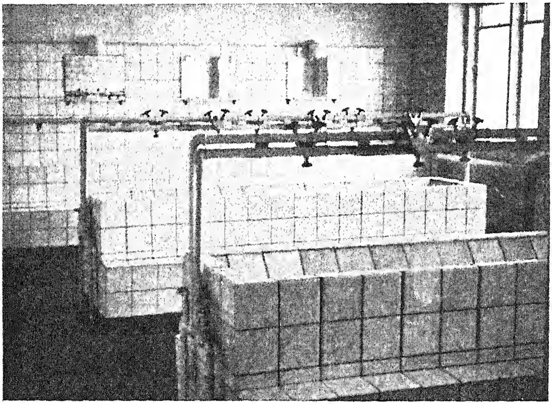

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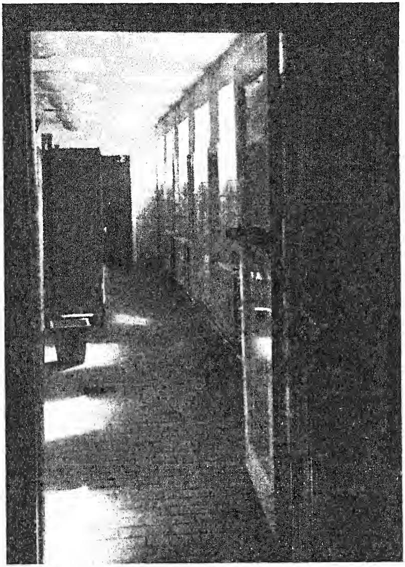
FIG. 7. CLOAKROOM OF DESTRUCTION PLANT



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The autoclave for sterilization of manure and waste water is also connected with the "clean" department.

Danish regulations

In Denmark regulations have been set up governing the treatment of the material of the destruction plants as follows :

(1) All products delivered to a destruction plant must be destroyed, i.e., sterilized. Such deliveries involve raw goods (i.e., carcasses, parts of dead or slaughtered animals, fish, fish offal, or other raw material) and coagulated blood, autoclave waste, etc., from slaughterhouses and meat establishments. Blood albumen to be used for fodder must be sterilized. Imported meat-, bone-, and blood-meal must be sterilized. The veterinary inspector for meat control will advise the establishments and the controlling officers when such imported goods will arrive for sterilization. On arrival at the destruction establishment, products such as those mentioned must be taken to the " unclean " department and may not be placed elsewhere : nor may they be removed before sterilization has taken place without special permission from the Veterinary Directorate. Meat- and bone-meal, etc., sent for sterilization in larger quantities than can be kept in the " unclean " department without interfering with the other work of this department, may not be received.

(2) Sterilization of raw materials must be carried out in a dry-render in which they are heated under constant stirring to at least 125°C, corresponding to a manometer pressure of 1.37 atm. (kg/cm^2) in the boiler for at least 15 minutes after the air has been driven out. The material is then dried until it reaches a temperature of about 105°C in the absence of pressure. This method assumes that the material has a considerable water content (at least 15%), and it should not be used for that with a low water content such as meat- and bone-meal, blood-meal, blood albumen, etc.

(3) When sterilizing products which do not contain considerable amounts of water, the material must be pulverized. No more than about 800 kg may be charged into a boiler holding 4000 litres. The sterilization must take place in saturated steam in a dry-render so fitted as to lead steam direct into the centre of the boiler. The air is carefully blown out of the boiler, and the material is treated with saturated steam under constant stirring. In 15 minutes the saturated steam is brought up to at least 1.37 atm. (kg/cm^2) corresponding to a temperature of 125°C. This minimal pressure and temperature must be maintained for at least 45 minutes.

(4) Sterilization of manure and waste water from the " unclean " department of the establishment must take place in an autoclave. The material must be fluid when treated (i.e., manure must be mixed with waste water). Treatment takes place by leading steam into the bottom of the autoclave and heating to a temperature of at least 115°C (0.7 atm.) for at least one hour.

(5) No other methods of sterilization than those mentioned may be used unless written permission has been given by the Veterinary Directorate.

(6) Hides and skins must be salted for at least 14 days before being delivered from the destruction plants. Hides and skins of animals from districts closed as a result of foot and mouth disease must be washed thoroughly with a 1% soda solution both on the hairy side and on the meat side before being salted down.

(7) Horse-tail hair, cow-tail hair, horseshoes, tethers, rope, sacks, etc., must be placed in a 1% solution of formaldehyde (made by adding 30 g of formalin to one litre of water) for at least 24 hours ; when the tail hairs have been cut off, the tail must be destroyed as described in section (2).

(8) Hoofs and horns must be sterilized as described in section (2).

(9) Products received for destruction must normally arrive in approved trucks or in approved packing belonging to the plants (generally metal drums). The trucks and packing must be carefully cleaned with hot water and then thoroughly disinfected with a 5% creolin solution. If goods are delivered in other trucks or in other kinds of packing, cleaning and disinfection takes place in the same way. Packing which cannot be cleaned and disinfected effectively (e.g., paper or cardboard, or defective wooden packing) and packing material which normally would be re-used for foodstuffs (e.g., ordinary fish boxes) may not be returned but must be destroyed by burning, if the plant has facilities for it, or must be broken up and placed in a creolin solution (at least 5% for at least 24 hours), and subsequently removed for burning.

(10) The destruction apparatus mentioned in sections (2) and (3) must be fitted with manometers giving the pressure both in the steam-jacket and in the boiler, and a thermometer giving the temperature in the boiler. The destruction apparatus mentioned in section (4) must be fitted with a manometer and a thermometer giving the pressure and temperature in the boiler. Manometers and thermometers must be checked to ensure that they function correctly and synchronize ; if not, they must be repaired or changed. The following tabulation is given as a guide for temperatures and corresponding manometer pressure.

Temperature in °C	*Pounds per square inch*	*Atm. (kg/cm^2)*
100	0.43	0.03
101	1.00	0.07
102	1.56	0.11
103	2.13	0.15
104	2.70	0.19
105	3.27	0.23

Temperature in °C	*Pounds per square inch*	*Atm. (kg/cm²)*
106	3.84	0.27
107	4.55	0.32
108	5.12	0.36
109	5.84	0.41
110	6.54	0.46
112	7.95	0.56
114	9.38	0.66
116	11.10	0.78
118	12.80	0.90
120	14.51	1.02
125	19.50	1.37
130	24.70	1.74
135	31.00	2.18
140	38.10	2.68
145	45.90	3.23
150	54.60	3.85
160	75.30	5.30

(11) If a carcass from an animal suffering from anthrax is delivered to a destruction plant, treatment must be carried out in as isolated a place as possible. All parts of the carcass, including the hide, contents of stomach and intestines, blood, etc., must be sterilized as described in section (2). The place of slaughter must be cleaned and disinfected carefully according to the instructions of the veterinary officer. This also applies to trucks and implements which have been in contact with the carcass. Persons who have dealt with the carcass must wash carefully and change their clothes immediately after finishing the work, and the clothes must be disinfected as described in section (7), before being washed. Footwear must be washed thoroughly in 5% creolin water.

(12) Meat- and bone-meal, blood-meal, fish-meal, etc., sterilized at one destruction plant may be delivered direct to the "clean" department of another destruction plant. This also applies to vegetable feeding-stuffs and other compounds (chemicals, etc.) used for the production of feeding-stuff mixtures at the plant.

(13) Meat- and bone-meal, blood-meal, and similar imported end-products received for sterilization must be subjected to an examination when treated before the goods are delivered from the plant. The samples for examination are taken according to the following rules: When the material has been treated it must be filled into clean sacks immediately. A sample is taken from each consignment (or—for larger consignments—from every 25 tons). The consignment in question (or the 25 tons) must be kept separately, and marked with a special number for identification. A small teaspoonful, from 100 sacks chosen at random, is taken, and the total quantity is filled into one bag (for example, a clean, thick paper bag)

and given the identification number of the consignment. Sampling is done by a worker employed in the " clean " department of the establishment under the supervision of the chief veterinary officer or the attendant. The veterinary officer or the attendant (in the latter case the name and address of the veterinary officer must be given) sends the sample to the State Veterinary Serum Laboratory, together with a completed form supplied by the veterinary inspector. The consignment must not be delivered by the plant before the Serum Laboratory has given written permission. The costs of the laboratory test, 20 kroner (approximately $3) per sample, are paid by the destruction plant.

The last point of the regulations needs, perhaps, some explanation. As stated, it concerns imported meat- and bone-meal, blood-meal, and similar products. All products of this kind imported into Denmark have to be re-sterilized at a destruction plant because it has been found that many such imported goods had not been treated carefully enough, and were still infectious when offered for sale as animal fodder. Among bacteria found which are pathogenic to animals were different types of salmonella.

General recommendations

This paper has so far dealt with what can be done to prevent infection being spread from dead animals and condemned meat to other animals or man ; it is also, however, of importance to take care that waste water from destruction plants does not pollute the streams or lakes into which it is discharged. The waste water contains a rather high amount of organic material, and if it is not cleaned it will putrefy and spoil the natural vegetation and destroy the fish. It may thus be necessary to establish a treatment system for the waste water ; such systems are generally similar to those used for sewage water from towns, but are built on a smaller scale. If the waste water from a destruction plant is connected with the sewage system of a town, there may be no necessity to treat the water before it is discharged from the plant.

As the smell from a destruction plant may be rather unpleasant, it may be necessary to install apparatus to diminish it. The worst smell comes from the internal cylinder of the dry-render when the pressure is taken off. By condensing the vapour in a water-condenser (see Fig. 8) before the air goes out, it is possible to keep the smell within very narrow limits. Destruction plants should not be sited in towns, but it does happen that a plant placed in the neighbourhood of a town will, as time goes on, find itself one day surrounded by residences. In such a case, it will be necessary to be even more careful to avoid the escape of odours to the surroundings. Such a plant is situated on the outskirts of Copenhagen, and there, suction

FIG. 8. WATER-CONDENSER FOR VAPOUR FROM INTERNAL CYLINDER OF DRY-RENDER

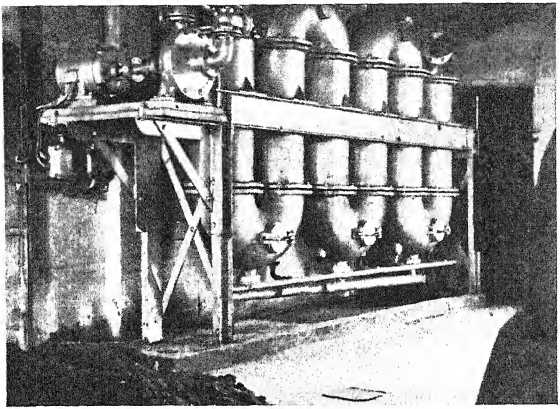
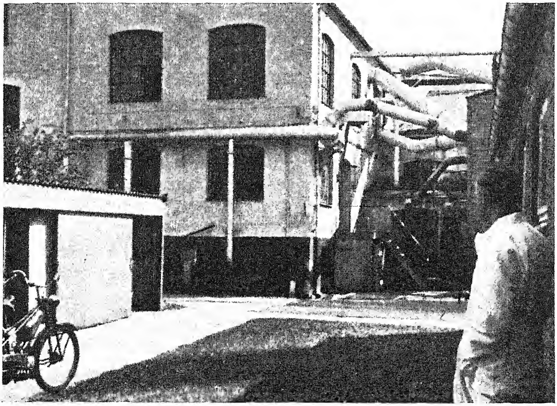


FIG. 9. AIR-SUCTION PIPES LEADING VAPOURS FROM DESTRUCTION PLANT



pipes are installed in all rooms (see Fig. 9), leading the air from these rooms, together with the air from the water-condenser, through a tower with coke and a waterspray so that the odorous materials are adsorbed onto the surface of the coke. Furthermore, the air is treated with ozone to oxidize remaining odours before the air is released. In spite of all efforts, however, it is impossible to remove the smell completely and, as this type of equipment is rather expensive to run, it is highly advisable to avoid placing a destruction plant in or near a town.

To ensure that the hygienic regulations for destruction are followed, it is necessary to have some supervision of these plants. In Denmark, all destruction plants have to be authorized by the Ministry of Agriculture, who employ a veterinary officer at every plant to see that all is carried on according to the regulations. This officer comes several times a week to the plant, gives his advice, takes samples, etc., while the daily supervision is done by a layman as assistant to the veterinary officer.

It has been suggested that it would be preferable to have the "millery" outside the destruction plant. This, of course, would diminish the risk of infection of the meat- and bone-meal. In Denmark we are therefore trying to move the "milleries" for meat- and bone-meal away from the destruction plants to the special establishments for feeding-stuff mixtures. This removal is, perhaps, impossible for some of the existing plants, but whenever a new plant is built or an old plant is reconstructed these ideas will, no doubt, be followed, as a small link in the chain of efforts to make the world more sound and healthy for man to live in.

Reclamation of By-Products

It is sometimes said as a joke that the only part of the animal lost in the modern industry of animal slaughtering is the last cry, but what was at first said as a joke has become more and more a truth. This is primarily due to the development, during the past 30 years, of the pharmaceutical industry, which has learned to produce from different organs of slaughter animals many of the enzymes, hormones, and the like found necessary to the regulation of the functions of life in man and animals. Moreover, the old by-products, such as skin, blood, hair, etc., are still of outstanding value and are impossible to replace. During the second World War, when vegetable proteins were scarce, farmers in Europe learned that animal proteins are of great value as protein fodder for animal husbandry, and while before the war Denmark, for example, exported much meat- and bone-meal, this is now imported, even though the country itself produces more than ever.

Meat- and bone-meal, gelatine

Meat- and bone-meal is, in Denmark, subjected to State control for fodder mixtures. The producer must guarantee a certain amount of digestible proteins in each bag of fodder sold, according to a guarantee label in each bag giving the percentage of digestible proteins and the number of Scandinavian fodder units the meal contains. If it is shown by the State control that the guarantee has not been met, the producer in question is heavily fined.

Gelatine is also produced from bones, largely veal bones, which contain most collagen tissues. When the bones are stripped for meat they are brought to the gelatine plant, where the fat is extracted with petrol and the minerals are removed with hydrochloric acid. Next, the balance (ossein) is treated with precipitate to transform the collagen to soluble glutin. The rest of the process is then like that of gelatine production from pork rinds.

Blood

The blood of the slaughter animals in most of Europe has long been used for the production of a special sausage, " blood sausage ", or for " blood puddings "; as slaughter became industrialized, however, it was impossible to use the large quantities of blood for this purpose, and instead it was made into blood-meal for fodder at the slaughterhouses. This is still done. The blood is led from the killing-floor into a container and from there pumped into a boiler where it is cooked with steam while agitated. The liquid is then drained off and the coagulated blood is pressed, dried in a drying drum till the water content is below 10%, and finally sent through a hammermill where it is ground. This method is applicable in places where, owing to sanitation conditions, the producers are required to process the blood instead of letting it flow into the sea or into sewers, and where the feeding value is of no great consequence. When the liquid is drained off from the cooked blood, about 13% of the dry-matter content of the blood—that with the highest nutritive value—is lost. Other methods have therefore been developed to save as much of the dry-matter content as possible, since it is a question of saving all nutriment and producing a valuable feeding-stuff. One method is to spread the blood in a thin layer on the surface of a heated metal cylinder which rotates and, after drying, scrapes the dried blood off. Another is to send the blood in a thin layer on a moving belt through a hot-air tunnel, where it is dried and, when leaving the tunnel, scraped off the belt. As both these methods of drying blood are rather expensive in consumption of fuel, a combined blood boiler and drier in connexion with a vacuum plant has been used. It consists of a closed vacuum-tight boiler with steam-jacket and agitator. The blood is pumped direct into the boiler, or may be sucked

in by first putting the boiler under vacuum. Hot steam is then led through the blood while it is agitated, and the blood is coagulated at about 80°C. Next, the boiler is put under vacuum, and at the same time the steam-jacket is put under steam ; after being dried, the blood is ground in a hammermill. By this method the raw material is fully utilized, and at the same time one handling of the material is saved. However, as the blood is mixed from both sound and diseased animals, and the blood-meal is used as feeding-stuff, it is important to be sure that the end-product is not infectious.

Unfortunately none of the methods mentioned are safe in this respect. Of course, most of the bacteria in the blood will be killed at the temperatures in question, but the temperatures necessary to kill spores are never reached. It is also a fact that coagulated materials are much more difficult to sterilize than simple solutions. The only way to be sure of getting a fully sterilized blood-meal would be to dry the blood in a dry-render, as is done to some extent in Denmark. This method furthermore has the advantage of using the same machinery for meat-, bone- and blood-meal production, although the drying of the blood alone in this way is more expensive than the use of the vacuum boiler.

Blood is also used for technical purposes as albumen, either dark or light. Dark albumen is used for the glueing of plywood. The albumen is dissolved in water and precipitate is added to form a paste, which is smeared on the pieces of wood, which are then pressed together in a hydraulic press at a temperature of 80°-90°C ; the proteins coagulate and glue the wood. After coagulation the albumen is insoluble in water. Light albumen is used in the dyestuffs industry as glue in the dyeing of textiles and paper, and also in the leather industry, to give the leather a dressing before it is dyed.

To produce albumen, it is necessary to avoid coagulation of the blood. This is done either by stirring the blood to separate the fibrin from the blood, or by adding some anti-coagulating material such as sodium citrate. The blood is centrifuged to separate it into serum (about 55% with about 10% dry matter) and the red residue containing blood corpuscles (about 45% with about 35% dry matter). Drying then takes place. Some of the water is first evaporated in a vacuum plant, and after that dried in a niro-atomizer, a closed cone-shaped tower placed with the vertex downwards. Here the serum or blood is sent in from the top as spray and meets with an upward-moving flow of hot air. In this way, the serum or red-blood residue is quickly dried and the powder falls to the bottom of the tower, where it is immediately filled into sacks.

To some extent dried serum, under the name of blood plasma, is used to replace white of eggs. If it is to be used in this way for human consumption, special precautions must be taken when the blood is extracted

from the animals, to make sure that only the blood of sound animals is used, to avoid infection or contamination, and to keep the drying machinery clean, according to the same principles as those used in the dairy industry. When the fibrin is separated from the blood, it is usually prepared as dry fibrin powder, which is used in the pharmaceutical industry as a rather pure lecithin. After separation, the fibrin is washed with water, drained, dried under vacuum, and then ground.

Hides, hair, hoofs

The hides of the slaughter animals are used for preparation of leather at tanneries. The cow-hair is collected at the tanneries and sent to special establishments where it is washed in flowing water in large water basins, and then centrifuged to extract as much water as possible before drying takes place on a moving belt in a drying-tunnel with hot-air flow. The cleaned and dried cow-hair is used for felt preparation (e.g., in hat manufacture). In most countries the skins of pigs are not removed when they are slaughtered, but after scalding the bristles are scraped off and heated in the same way as cow-hair. The cleaned and dried pig bristles are used for upholstering furniture and for "hairlock", which is rubber mixed with pig bristles and used for seats in cars, chairs, etc.

The offal of the hides from tanneries is used for glue preparation. At glue factories the offal is treated with a precipitate solution to make the collagenous tissue soluble by transforming the collagen to glutin, which is then drawn out with hot water. From this glue solution most of the water is evaporated in a vacuum plant, and the glue is dried on a heated moving belt or on salvers in a drying-tunnel. As it becomes more and more usual to remove the skin of the hams and shoulders of pigs used in the canning industry, a large quantity of rinds is available for the gelatine industry. The rinds without fat are treated with hot water to draw out the gelatine, and the solution is evaporated under vacuum and dried on a heated moving belt or in a drying tunnel. The dried gelatine is used in the household as isinglass, and for technical purposes, for example, as a basis for photosensitive membrane fibres.

Hoofs and claws are ground and used as fertilizer.

Fat

Technical fat from destruction plants and lower qualities of fat from fat-rendering plants are used for soap production.

Organs

Catgut is produced from the small intestines of sheep. Livers and lungs are of considerable value for pharmaceutical preparations, and

various organs of internal secretion are in great demand in this industry—for example, the pituitary gland, the thyroid gland, the pancreas, the mucous membrane of the stomach, the suprarenal glands, the ovaries, the testicles, and also the brain and the spinal cord. The collection of these organs generally presents no difficulty from a sanitary point of view as they are taken from animals unconditionally passed, but in some cases, such as in the removal of the pituitary, a special apparatus has to be constructed, and immediate freezing of the organs is required so that the content of the enzymes or hormones will not be diminished or spoiled before preparation takes place.

Often the slaughter in one place is on too small a scale to supply a pharmaceutical factory. It may be of value to collect the organs and forward them, frozen, to one of these plants. The whole world is a market; livers from New Zealand and Australia, and pancreases from the USA and other parts of the world, are shipped to Europe and used for medical preparations; the distance from the place of slaughter to the factory is thus of minor importance.

Although meat production for human food is still the most important reason for slaughtering of animals, the utilization of the by-products is of much greater value than is generally considered—and not only for reasons of economy. For millions of people all over the world (for example, the many suffering from diabetes) it is increasingly essential for life that organic preparations be available.

Danish regulations

According to the Danish meat control regulations, all meat, offal, and meat products condemned at the time of meat inspection must be rendered useless for human food by treatment with a 5% creolin solution and, together with other meat and offal that are not to be used for human food, must be delivered to an authorized destruction plant. If these regulations were followed strictly, it would be impossible to get meat for animal fodder for zoos and breeders of fur animals, or to get raw materials for organo-pharmaceutical products. Therefore the Danish regulations give two exceptions to this rule:

(1) Glands, brains, and spinal cords, etc., which are sound and fresh and derived from healthy animals may be sold directly by the slaughterhouse to a pharmaceutical factory or to some other special concern approved by the Ministry of Agriculture. Transportation must take place in clean, solid, and waterproof containers which are marked conspicuously and distinctly: "Offal for technical use. Inedible". If such goods are not shipped or used for the said purpose they must be delivered to a destruction plant.

(2) Sound and fresh parts of healthy animals may be sold by a slaughter-house for animal fodder directly to an animal breeder or an association of animal breeders. Transportation must take place in clean, solid, and waterproof containers, conspicuously marked: "Animal fodder". If such goods are not shipped or used for the said purpose, they must be delivered to a destruction plant.

The meaning of "sound and fresh parts of healthy animals" has always been under discussion, and different definitions have been given within the two limits of interpretation: (1) only parts from animals unconditionally passed; and (2) all parts considered by the inspecting veterinary officer to be harmless for the said purpose, regardless of the judgement passed on the carcass. It has been stated that the most strict definition should be followed, since what is harmless for one purpose may be injurious for another, and the inspecting veterinary officer will never be able to be sure—whatever is said—for what purpose exactly the material will be used.

Netherlands regulations

In countries in which meat is scarce it will, however, be difficult to maintain such rules, and even in some countries with a rather highly industrialized meat production the question is considered from another point of view. In these cases, it is for the inspecting veterinary officer to determine whether the condemned material is to be considered fit for animal fodder or pharmaceutical purposes or not. It stands to reason that this condemned meat must not be injurious to the health of the animals for which it is destined, nor cause the spread of contagious cattle diseases. Special precautions have to be taken to prevent the fraudulent sale of condemned meat for human food. Thus, the Netherlands Meat Inspection Act makes it possible in Holland to use condemned meat as fodder for animals and for pharmaceutical purposes, but such material may only be delivered to special establishments licensed by the Ministry. If a zoological garden, a circus, a fur animal-breeding farm, or a pharmaceutical factory has obtained a licence, it is supplied with a register, in which the inspection service concerned has to enter the quantities of meat supplied, as well as the date of supply and the signature of the inspecting veterinary officer. Every inspecting service authorized to supply condemned meat to the said establishments has a special register in which each supply of condemned meat is entered, together with the name of the receiving establishment. At the end of every year both kinds of registers are sent to the Veterinary General Inspection Agency of Public Health for checking. Before permitting the supply of meat for animal fodder, the inspecting service sees that deep incisions are made in the condemned meat and methylene-blue solution poured over it. Transport of the meat is also

covered by the register, and must be effected directly and without delay from the place of receipt to the establishment concerned. Tightly-closed means of conveyance must be used, which cannot leak and can be opened only with keys, one of which is to be kept by the inspecting service and the other by the owner of the establishments. No further keys must be in circulation. The establishments are obliged to deliver all offal from condemned meat which is not used for feeding purposes—for example, bones—to a destruction plant.

For pharmaceutical purposes only, the supply of condemned livers and lungs is allowed : that is to say, livers condemned on account of parenchymatous degeneration, fat infiltrations, melanosis, multiple necrosis, blood stasis, anaemia, haemorrhage, telangiactasis, distomatosis, tumours, pollutions, chalicosis nodularis, and hepatitis parasitaria multiplex ; and lungs condemned for pleurisy, blood stasis, haemorrhage, tumours, pollutions, lung worms, distomatosis, and other parasitic affections except echinococcosis. In every case the inspecting service decides whether, and to what extent, such livers and lungs are fit for pharmaceutical purposes. The livers and lungs which are considered for processing into pharmaceutical preparations are deposited at slaughterhouses designated for the purpose in separate confiscation buckets which can be closed with a padlock and bear the name of the licensee. As regards the keys of the padlock, a similar arrangement is established as that for condemned meat for animal fodder.

Every consignment of condemned livers and lungs must be covered by a document issued by the inspecting service. A duplicate of this document is sent to the chief veterinary officer of the inspecting service in whose area the pharmaceutical factory concerned is situated.

The final residue of the processing of condemned livers and lungs must be delivered to a destruction plant.

The Netherlands regulations on this question may be considered rather complicated, but there is no doubt that if condemned meat is to be used for animal fodder or pharmaceutical purposes it will be necessary to establish a strict control system to secure that the material is used as intended, and is not sold, either raw or processed, for human food.

HYGIENIC CONTROL OF MEAT IN MARKETS AND IN FOOD-SERVING ESTABLISHMENTS

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The hygienic control of meat in markets and in food-serving establishments is a necessary part of general food-control measures, the object of which is to ensure that the consumer obtains foods that, as far as possible, are pure, fresh, and unadulterated at the time of sale. Food purity may be regarded in two ways. First, it is essential that foods offered for sale to the public should not contain specific pathogenic bacteria or poisonous substances liable to cause disease. Secondly, at the time of sale, food must not be contaminated with certain other species of bacteria (staphylococci, streptococci, *Bacillus cereus*, *Clostridium welchii*, etc.) in numbers such as may prove injurious to health, whether consumed on the spot, in a food-serving establishment, or after keeping for a relatively short time in the home.

It is common knowledge that, in many homes, the conditions under which food is stored are far from ideal. From a hygienic as well as from an economic point of view, it is therefore essential that food be in such a condition at the time of sale that it can safely be kept for a reasonably short space of time even under non-ideal conditions.

That food should not be adulterated goes without saying, especially by the addition of substances which may be harmful to human beings or are used to disguise its poor condition.

There is a tendency in many places nowadays, in the meat retail trade, to break away from the shop dealing solely in meat towards the establishment selling a variety of meat products and ready-to-serve dishes prepared either on the premises or by wholesale dealers. Indeed, many of these shops also deal in articles of food other than meat, so that a great variety of foods may come to be sold under the same roof. These developments have raised a number of new control problems, as regards both the methods of preparing foods and the construction, equipment, and fitting-out of shops.

As a basis for control, there must be official regulations governing the construction and running of establishments. It is obviously easier to lay

down such rules than to enforce them; usually economic considerations preclude the stationing of a supervisor in every establishment during working hours. Inspection to ensure that the construction and fittings of the shop meet requirements is easy enough, but a number of difficulties arise when an attempt is made to find out whether the work is being done in a thoroughly hygienic way.

Meat control in markets and other establishments includes control of the raw material used, inspection of all stages of the preparation of meat products, and control of the finished article.

Raw Material

With adequate meat-inspection services in the slaughterhouse, it may be assumed that meat delivered to markets and food-serving establishments is sound. Control of the raw material, therefore, is concerned only with changes which may occur after delivery.

Construction and Fitting-out of Premises

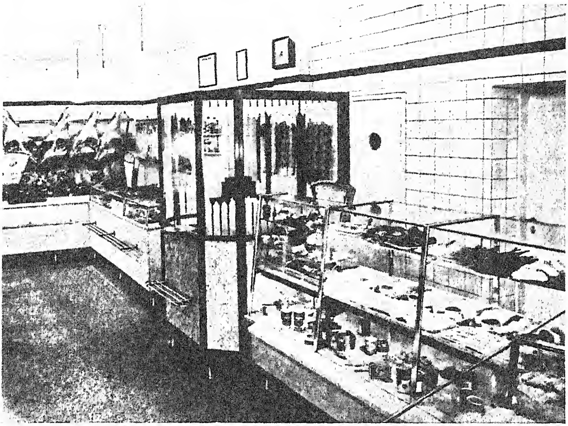
The object of control is to maintain hygienic conditions so that meat will not be exposed to contamination. The layout and equipment of premises used for the sale and preparation of foods must therefore be such as to facilitate the maintenance of thorough cleanliness.

It is not infrequent for rather strong exception to be taken to the requirements laid down by the hygienist for the furnishing and equipping of such premises. Objections may be raised on grounds of expense, on the assumption that such requirements are prescribed solely for the purpose of obtaining an aesthetic background for the sale and preparation of foods. Nothing could be more mistaken than this way of looking at the matter. It is practical considerations that require the provision of cemented flooring with drainage, tiled walls, and counters and tables in stainless steel or marble or some similar material, as well as of suitable receptacles and utensils, so as to make possible thorough and effective cleansing of the premises (see Fig. 1).

Acceptance of these reasonable hygienic requirements automatically rules out the sale of meat from open stalls in market squares, etc. Approval for such places of sale cannot be granted, because of the contamination to which the meat is exposed, and many public authorities have prohibited this practice.

The tremendous importance of the thorough cleansing of premises in which meat is sold leads to consideration of any circumstances that may

FIG. 1. MEAT SHOP EXEMPLIFYING EXCELLENT HYGIENIC CONDITIONS



hamper cleaning, such as overstocking, for instance. Reasonable space must be allowed and the necessary authority must be available to limit the stock-in-trade or quantity of meat products prepared on any premises.

Minimum space requirements might be laid down, but it is almost impossible to generalize, because the size of a shop depends largely on its turnover. Each case must therefore be dealt with individually. In shops where most of the meat products are prepared on the premises, it might reasonably be stipulated that the preparation room be not less in size than the public shop. Hence, consideration might be given to a regulation that such premises should consist of at least two rooms, one to be used for serving the public and the other for preparing the meat, and that access to the preparation room should be limited strictly to the staff. This would seem to be an indispensable provision.

The need for a regulation of this sort is all the more obvious in the case of premises where meat products are prepared on a substantial scale. As for other premises, a certain amount of processing of meat is always done in every place in which meat and meat products are sold. There will always be products which will not keep for long in a raw condition—for instance, minced meat and forcemeat. When still unsold after expiry of

the safe time-limit, it is general practice to take some action to preserve these foods, either by boiling, frying, or—in certain cases—salting. Facilities for this purpose must accordingly be available; they should not, however, be installed in the public shop (see Fig. 2, 3). The thorough

FIG. 2. MEAT SHOP: HYGIENIC SALTING-ROOM

washing of the receptacles for the meat likewise demands certain facilities, which again are best situated in a separate room. Naturally, the size can be adapted to the scale of the operations, but the provision of two rooms at least must, in all cases, be considered a reasonable requirement.

FIG. 3. MEAT SHOP: HYGIENIC COOKING-ROOM

Temperature and Ventilation

Temperature regulation and the ventilation of premises used for the sale or preparation of meat are problems of importance. The question of ventilation may be solved satisfactorily in a number of ways, but temperature control presents far greater difficulties. As a general rule, prohibition of artificial heating beyond a certain maximum will probably prove the easiest solution. A basic requirement, however, is that any establishment where meat is sold should possess a refrigerator large enough to take all

the food that requires low-temperature storage. This should apply alike to butchers' and delicatessen premises, and to restaurants and other public eating-houses.

Sale of Meat in Conjunction with Other Produce

In controlling establishments dealing in meat, the problems surrounding the sale of meat and meat products in conjunction with other kinds of food cannot be avoided. There is much talk at the present time of the development of retail food outlets, both in the trade itself and among consumers. This is due, in particular, to the trend towards concentration of trade in larger stores selling practically every kind of food as well as other articles, and to the introduction of self-service methods. The argument is frequently advanced that the rapid development in cooling and packing techniques has outdated the view held hitherto that special premises are needed for the sale of meat and meat products. It is maintained that, once these processes are fully developed, a shop of any size or type whatsoever should be allowed to deal in meat and meat products, provided that these are adequately packed and that the shop possesses a refrigerator for storage purposes. Two issues arise in this connexion : first, whether such a development, once fully achieved, would be desirable from a hygienic point of view ; and, secondly, whether conditions in such shops would permit adequate control of meat.

It is well known that bacteria found on fish and shellfish, and, more especially, on uncleaned vegetables and edible roots, will acquire far better conditions for growth when transferred to meat. Growth will occur relatively quickly, particularly if the meat is not kept at an absolutely ideal temperature, and undesirable changes and possibly even poisonous substances will be produced in the meat. Accordingly, foods such as raw vegetables (potatoes or other edible roots, cabbage, lettuce, parsley, etc.) and raw fish and shellfish should not be stored on premises where meat is sold or prepared. This view is recognized in Denmark and in some other countries, and has been embodied in official regulations, but there are indications that elsewhere it has not been accepted or that no practical conclusions have been drawn.

If meat and raw vegetables are allowed to be sold from the same premises, it is almost inevitable, especially in small shops, that the staff will handle both and that contamination of the meat will result, even though instructions have been issued that the goods are to be kept apart and hands cleansed frequently. Where vegetables or other foods are a recognized ingredient of a prepared meat dish, it must at least be stipulated that they should not be brought into the preparation room until tho-

roughly cleansed elsewhere, and, furthermore, that preparation should begin immediately thereafter (by boiling, frying, pickling, etc.).

In restaurants and other public eating-establishments, the same principles should apply. The cleaning of fish and vegetables should be done in a separate room and these foods should not be brought into contact with meat without prior cleansing. It is realized, of course, that in many smaller establishments the fulfilment of these requirements will meet with great obstacles.

It has often been argued that regulations requiring separate sale or preparation of meat and of other foods are nullified in practice by the housewife, since a similar separation in the home is impracticable. The two are not by any means comparable, however. In the former instance, the sale of food is to comparatively large bodies of consumers, and the official health authorities are obliged to take measures that will safeguard the consumer from possible harmful effects arising out of food-handling. In the latter case, circumstances within the family alone are involved, the risk is less, and no interference is possible, except teaching the consumer the importance of separation. Faulty storage and preparation of food in the home often results in contamination and the subsequent transmission of food-borne disease.

In all the circumstances, therefore, shopkeepers wishing to sell a variety of different articles from the same premises should have a separate department for meat, at any rate for the sale of unpacked meat and meat products.

Sale of Packed Meat

It may be assumed that the sale of packed meat and meat products from refrigerator cabinets (canned goods are not concerned here) occurs chiefly in self-service shops. There are still many problems that require further investigation in this connexion. There is no doubt that, even when sold ready-packed from a refrigerator cabinet (e.g., in cellophane), meat products must be disposed of within a relatively short time if their quality is not to be impaired. This means that a rapid turnover is desirable. Bacterial growth is not ruled out at low temperatures, and the questions arise whether the possible higher humidity in ready-packed goods would affect such growth, and whether the most appropriate type of packing has yet been found.

It goes without saying that meat and meat products must be absolutely fresh when placed in refrigerator cabinets. In order to ensure this, shops using premises for this type of sale that do not comply with stipulated requirements for the cutting-up, preparation, and packing of meat must have an adjoining meat department for this purpose. A stipulation to this

effect would confine this type of trade to the larger shops that employ qualified staff in the meat department. From the hygienic and meat-control standpoint, no shop without the requisite equipment for dealing in meat should be permitted to sell meat products prepared or packed elsewhere, irrespective of whether or not it has a refrigerator cabinet. Should this be allowed, products not rapidly sold will constitute a major problem, and an increase in this system of retail trade will result in bringing into the meat trade a number of persons with no qualifications whatsoever for judging the freshness of meat. Furthermore, an expansion of the meat trade through these channels would make it practically impossible for public authorities to enforce satisfactory standards of hygiene.

Daily Food-handling

The equipment and arrangement of an establishment is an important factor in securing products of good hygienic quality, but the manner in which the staff carries out the daily work is no less important. It has often been found, however, that an improvement in hygienic conditions has brought about a complete change in the staff's attitude towards cleanliness, which, in turn, has led to a substantial improvement in the quality of a product.

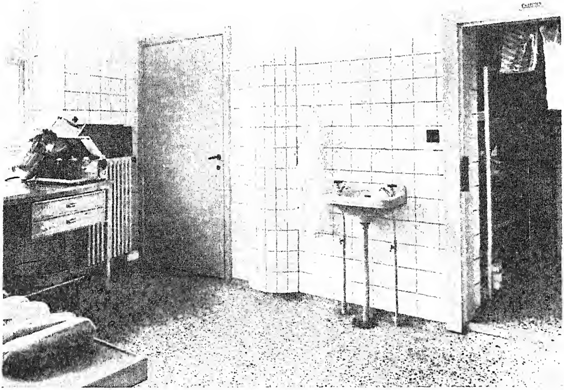
Somewhat detailed regulations are necessary to govern the maintenance and cleaning of food premises, measures to combat noxious animals and flies, the personal hygiene of the staff, and other related matters. Observance of such regulations under everyday conditions will depend upon convincing the proprietor and shop staff of their sound basis, and this may be considered a long-term policy. As a matter of fact, many of the errors that are committed more often result from ignorance and failure to appreciate the problems involved than from a defiance of the prescribed regulations.

For instance, where regulations prescribe that prepared foods not consumed immediately after preparation must be cooled down as soon as possible and not kept for any length of time at a temperature above 8°C (46°F), it must be explained that certain temperatures between 10°C and 50°C (50°-122°F) are dangerous for meat products. To cite a case in point : fresh-cooked liver paste was kept overnight at too high a temperature, with the result that, at the time of sale, it was found to contain a considerable number of *Bacillus cereus* deriving from contaminated flour used in the preparation. The proprietor of the shop was acting in perfect good faith, in the belief that heating would leave the liver paste in perfect condition. Since it was explained to him how the spore-forming bacilli grow, he has not repeated this mistake.

A prohibition against the decoration of meat with raw lettuce, parsley, etc., is likely to be received reluctantly by those who do not understand the dangers involved. An explanation that bacteria may be transferred to the meat and there have better conditions for growth will often overcome this reluctance and lead to acceptance of the prohibition as reasonable. Where unwillingness to grasp the facts is maintained, however, further steps must be taken to enforce the regulation.

Particular attention has rightly been drawn to minced meat, forcemeat, and sausages containing raw forcemeat. A number of ways have been tried out in order to secure a proper standard of freshness for these products, which as a rule contain many organisms. Consideration might be given to stipulating that meat must be minced in the presence of the customer; many housewives prefer this. It must be admitted, however, that an official regulation to this effect would greatly inconvenience shop-dealers during rush hours. Alternatively, it might be recommended that minced meat and raw forcemeat should be kept for a very short time only in the shop; here, however, it would be very difficult to ensure observance. Two further proposals might be examined: first, to require minced meat

FIG. 4. MEAT SHOP: HYGIENIC CONDITIONS IN COOKING-ROOM



Note special cooling-room.

and forcemeat to be kept under refrigeration, except during rush hours, and, secondly, to order that products not sold by closing time each day should be boiled or fried prior to later sale. There would seem to be no obstacles to the observance of these two rules, but their application in the daily routine should be backed up by a satisfactory explanation of their soundness.

Reports of food-poisoning outbreaks originating in public eating-houses serve to emphasize the need for special precautions in food-handling in these establishments. Particular attention should be given to the practice of preparing food a considerable time before serving and letting it stand at temperatures favouring the growth of organisms.

The most difficult problem in food control is undoubtedly that of staff supervision. By insisting upon premises with adequate equipment and installations, the staff may have the best possible conditions for maintaining standards of cleanliness (see Fig. 4). Public authorities can also check that toilets are kept in perfect order and are provided with wash-basins. They can insist on the wearing of clean working-clothes, and so on. But no amount of regulations will necessarily ensure the maintenance of personal hygiene in the daily routine, and a better method is to instil into the staff habits of personal cleanliness by specific instruction on how unclean conditions may affect the quality of the food they are handling. The occurrence of disease among food-handling staff is another factor that is most difficult to control. Here, again, enlightenment on possible consequences is probably the only practical way of obtaining satisfactory results.

Staff regulations must, of course, be supplemented by rules for protecting goods on display from contamination by the public. Many customers show a marked inclination to finger the meat they are about to buy. This should not be allowed under any circumstances, and care should be exercised to prevent contamination from coughing or sneezing on the part of the public. The best way to achieve this is to have the meat screened off from the public.

Practical Control and Approval of Premises

The first condition for practical control in markets and food-serving establishments is that the sale and preparation of meat and meat products should be carried out only in rooms officially approved for the purpose. Approval should also be obligatory for new or remodelled premises. Before new building or conversion is begun, the plans should be submitted for expert examination. It is possible to lay down certain general directives, but each case will require individual attention in the light of the proposed business.

Sanitary regulations in some Danish towns stipulate renewed approval whenever a business changes hands, and the Danish Board of Health is empowered to approve new premises and to reconsider approval every five years. In this way an attempt has been made to ensure that new developments in the field of meat hygiene are followed up.

A far greater problem, however, is presented by establishments that have been in existence for many years and where neither equipment, fittings, nor working methods meet the requirements of modern hygiene. If the continued existence of the establishment is not made conditional upon the introduction of improvements, progress towards higher standards will largely depend upon the ability of the inspector concerned to convince the owner of the advantages to business and efficiency if hygienic conditions in the shop are brought up to standard. Again, where there is failure to appreciate the need for hygienic conditions, or unsatisfactory equipment and arrangements in premises offend against hygienic standards, pressure must be brought to bear on the proprietor. In the latter case, due account is generally taken of any attempts to improve matters by orderliness and thorough cleanliness. Incidentally, it is interesting to note that demands for modernization are often welcomed.

Inspection of Establishments

Except for very large establishments where permanent control can be maintained, periodic checks should be carried out. The question then arises of how frequently premises should be inspected. There are certain businesses where frequent inspection is essential to ensure proper handling of the meat, and others where fewer checks will suffice. Accordingly, a fixed number of inspections for each establishment should not be stipulated. Regulations may lay down a minimum number of inspections per year, but the exact number is open to discussion. On the whole, it is preferable for inspectors to have a certain discretion to use their authority wherever deemed necessary. Periodic inspection of establishments should cover the following :

1. Inspection of all rooms on the premises, with particular attention to standards of maintenance and cleanliness.

2. Search to ascertain that no prohibited goods are kept in rooms where meat is sold or prepared.

3. Search for illegal dyeing or preservative matter.

4. Inspection of waste-storage arrangements.

5. Inspection of utensils for cleanliness. (The inspector should be familiar with the problems associated with the various methods of

cleansing—use of dish-washing machines, dish-washing by hand, use of detergents, disinfectants, etc.)

6. Inspection of the stock-in-trade, including raw materials, goods in process of preparation, and finished goods. Particular attention should be paid to the freshness of the stock and to the fulfilment of any special regulations that may be in force at the time of inspection.

7. Survey of personal hygiene of the staff, and of facilities available for the staff. Any signs of illness should be noted and investigated.

Defects brought to light by the inspection should be brought to the notice of the proprietor and, if necessary, proceedings instituted. The main purpose is, of course, to have the defects corrected. Great attention should be paid to the instructive side of the control measures, particularly where errors are due to ignorance and a lack of understanding.

Laboratory Examinations

Opinions formed during the inspection of establishments and working procedures are, of course, largely based on a subjective estimate. The question arises whether it is possible to bring in a more objective element, by the use of supplementary laboratory examinations. There are three separate aspects to be dealt with.

(a) *Hygienic inspection of utensils*

Laboratory examinations can be of great help in checking whether utensils are kept in the required state of cleanliness. Whether the scope of such examinations is sufficiently large, however, in comparison with the extensive use of similar tests in milk inspection (continuous check on milk bottles, examination of production procedure at the dairy, and maintenance of satisfactory bacteriological standards) is open to question. Undoubtedly this type of check has greatly contributed to bringing about improvements in the quality of milk. But routine laboratory inspection of utensils in all establishments from which meat is sold is impracticable. Nevertheless, in isolated cases, an objective demonstration of the results of a laboratory examination may be helpful for indicating wrong procedures, and may often be more persuasive than a great many words to the proprietor and staff.

In food-serving establishments, on the other hand, regular laboratory inspection of table-ware should be made in conjunction with premises inspection, and, here, laboratory methods have proved satisfactory. Failure to appreciate the importance of thorough cleansing of dishes and table-ware has resulted in the use of unsuitable staff for dish-washing in

many food-serving establishments and, hence, the greater need for systematic examinations.

(*b*) *Bacteriological inspection of products* *

Where food poisoning is suspected, laboratory examinations will, of course, play a decisive role. But it might be possible to extend the use of laboratory examinations to other fields, and thus reach a more objective evaluation of the bacteriological quality of food.

Repeated attempts have been made to establish bacteriological standards for a number of different kinds of meat products. Great variations in bacterial content were obtained and considerable difficulty has been experienced in applying any such standards to raw food materials, because of the millions of organisms in every gram.

One is on much safer ground in judging the bacteriological status of foods heated in the course of preparation. Here, certain bacteriological standards may be set up for properly prepared foods. For a product such as liver paste, for example, it has been possible in Danish experiments to establish that the bacterial content can easily be reduced to 25 000 organisms per gram (80% of samples examined fulfil this condition) and similar standards have been attained for other cooked foods. Furthermore, where the bacterial content has been found to be excessive, laboratory examinations have made it possible to state the exact stage in production at which a faulty procedure was followed.

The general conclusion may be drawn that, in foods conforming to the bacteriological standard mentioned above, the chances of finding particular forms of bacteria in a number sufficient to cause food poisoning are very small indeed. Again, it is not difficult, when estimating the total count, to determine the occurrence of specific organisms (*Staphylococcus*, *B. cereus*, *Salmonella*, etc.).

Even if it were theoretically possible to carry out a routine bacteriological inspection of all kinds of cooked meat products, it would undoubtedly be difficult in practice. It should not be impossible, however, to undertake routine examinations of specific foods produced in larger centres supplying a number of retail dealers. In Denmark, weekly checks on liver paste have proved very useful. Routine laboratory examinations are made of this product as prepared at an establishment which delivers school lunches for about 9000 children a day. The routine tests are combined with weekly veterinary inspections of the establishment in question and of concerns supplying it with raw materials. Laboratory tests are also deemed necessary for the purpose of checking for the presence of illegal preservatives.

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* See also article by Jensen, page 235.

(c) Medical inspection of staff

Once the importance of the human element as a cause of food poisoning has been grasped, it becomes obvious that the personal health of the staff must be an important factor in the control of meat in markets and food-serving establishments. The problem this poses has been widely discussed and opinions differ considerably on how to handle the matter. It is more or less generally agreed that routine medical and physical examination of food-handling staff is not sufficiently sure, and is consequently of little value unless supplemented by laboratory examination. But there is a wide divergence of views on the value of routine laboratory examination of staff. It has been emphasized that the results achieved are not commensurate with the trouble and expense involved ; moreover, negative results are no guarantee that a person is not a carrier of pathogenic bacteria. On the other hand, it has been argued that expense should not be a consideration if such examinations serve to detect some human carriers of disease and thus prevent the transmission of infection to food.

It would seem impossible to lay down general rules, since conditions differ so widely from country to country. Where salmonellosis due to the consumption of contaminated meat products has not occurred for many years, the necessity of testing for *Salmonella* is open to question. Elsewhere, in places where *Salmonella* infections are less rare, serious consideration should be given to the introduction of such a practice, especially in larger food-processing establishments.

The value of laboratory examinations in ascertaining the occurrence of streptococcal or staphylococcal infections or the presence of human carriers of the causal organisms is problematical, because such conditions are usually intermittent.

As regards tuberculosis, in many countries organized examination for this disease has developed to such a point that it should be fairly easy to require food-handling staff to undergo one annual examination at a recognized diagnostic centre.

Nevertheless, whether one favours routine examination of staff or not, it must be evident that steps to enlighten and inform food-shop staffs on matters of hygiene, both from the personal and from the food-handling standpoint, are absolutely indispensable. Proprietors and workers must be made to realize their individual responsibility for the consequences that may arise from personnel remaining at work when unfit.

Every opportunity must be taken during inspection visits to instruct and advise in these matters, and this action should be combined with special instruction in hygiene for apprentices in the meat trade and courses for persons employed in the food industry generally.

Inspecting Staff

Hygienic control in markets and food-serving establishments cannot be satisfactorily accomplished by a mere police inspection to ascertain whether equipment and fittings comply with the regulations. This in itself provides no guarantee that an establishment is functioning satisfactorily in so far as hygiene is concerned. Indeed, the number and variety of problems involved in inspection procedure is very wide. These problems are not only general in nature, but pertain to individual shops. They may concern the equipment and arrangement of the premises or more complicated matters of production procedure, as well as the hygienic quality of the products on sale to the public. Manifestly, therefore, a specially trained staff is required if supervision is to yield satisfactory and reliable results.

In Denmark, the veterinary officer is accorded a key position in this important work, although the employment of other personnel in the control service is not necessarily precluded.

It is obvious that there must be co-operation between the veterinary officer and the medical officer of health in all matters pertaining to the health of food-handling staff. Co-operation between the veterinary surgeon and, for example, architects, civil engineers, and the special sanitary police is also necessary. Again, persons with special training in other subjects may also be employed with advantage in the control system—for instance, domestic science graduates, who may be especially helpful in the control of food-serving establishments.

Veterinary officers and others engaged in food-control work must have a thorough knowledge of food bacteriology, together with a special understanding of all the problems involved in the work. Food control is more than the mere detection of errors and defects ; its main object is to ensure that defects are corrected and that mistakes are not repeated. To achieve this end, the spreading of instruction and enlightenment in the appropriate quarters is required, and this can only be done by persons specially trained in this field.

Part VI

TRAINING OF PERSONNEL

TRAINING OF MEAT INSPECTORS

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In order to establish in any country a satisfactory meat-inspection service as part of public-health administration, certain requirements must be considered essential. There must be an adequate staff of competent, qualified inspectors, assisted, where necessary, by less well-qualified or lay inspectors; and there must be a definite and orderly system of inspection, guided by a workmanlike code of procedure and judgement.

General Principles

Uniformity in judgement in meat inspection cannot reach a satisfactory standard unless there is some degree of uniformity in the teaching given at the schools where meat inspectors receive their training. This training must not only embrace adequate instruction in the basic sciences, such as anatomy and physiology, but must also indicate the relative importance of the various pathological conditions that the person who becomes a meat inspector will inevitably encounter. The practicability of implementing these requirements must depend to some extent on: (*a*) the time which can be allotted to the teaching of the subject; (*b*) the facilities available for practical training; and (*c*) the standard of education of the personnel receiving the training and on whose shoulders the responsibility of meat inspection will eventually fall.

It would be impossible to include within the scope of this study a review of the meat-inspection services of the various countries and of the relative roles played within them by professional and lay staff. Suffice it to say that no person can become an efficient meat inspector unless he has paid special attention to the subject and has reached the degree of knowledge, dexterity, and efficiency which meat inspection demands today. The advantage that any officer can derive from a specialized training must depend very largely on his firm grounding in the anatomy, physiology, and pathology of animals, and in biochemistry and bacteriology; for this reason, and for this reason alone, the veterinary surgeon has come to play an increasingly responsible part in meat hygiene, not only in Europe but throughout the world. In some countries, however, the employment of the veterinary surgeon in relation to meat inspection has made little

or no headway, and the responsibility for this important branch of public-health work is therefore vested in the medical officer, who deputes the work to a lay inspector—an officer whose qualification to carry out such duties is the possession of a certificate obtained after a relatively short period of training.

Those who have had the opportunity of visiting abattoirs where laymen are in complete charge of meat inspection cannot but be perturbed at the empirical and unscientific judgements that are made, the chief and most serious criticism being that their lack of knowledge of the essential basic principles of meat inspection, and their inaccurate assessment of the relative importance of certain pathological conditions, compels them to apply a wide margin of safety in their judgement; as a result, much meat which is harmless and wholesome is condemned and destroyed. For several reasons, however, it is not practicable in every case to insist that all meat inspection be conducted by veterinary surgeons, and a realistic and practical outlook has been taken by many countries, which prescribe that the actual routine examination of carcasses and organs—itself an onerous task made still more onerous by constant repetition—may be conducted by laymen who are designated "detention officers" or some such similar term.

The duties of such a person are aptly defined in the appellation "detention officer" since, as a result of his routine post-mortem examination of all the animals slaughtered at an abattoir, he may release those carcasses which appear normal in every respect but must detain any which require a further and more detailed scientific inspection by a veterinary surgeon. Thus it is understood that in the law governing meat inspection in Germany a non-veterinary meat inspector who, during his post-mortem examination, detects tuberculous lesions in a carcass of beef or pork may pass judgement on the carcass only when the disease falls into the clearly prescribed classification of localized; all carcasses which, by the nature, disposition, or extent of the lesions, cannot be so classified are subjected to an expert veterinary examination. There is little doubt that the ideal arrangement is for the meat inspection to be placed in the charge of a veterinary surgeon, assisted by other veterinarians where the volume of work renders this necessary, and also by lay inspectors where required. In some cases lay inspectors have had previous experience of the butchering and slaughtering trade, and experience has shown that if they are men of a reasonable standard of education and are possessed of intelligence and integrity they fulfil a role of undoubted public-health value.

In considering the training which the potential meat inspector should receive it will be at once apparent that such training must be considered on two levels. First, there is the student of the veterinary college, who receives tuition in the basic sciences and in meat inspection during his

course ; and, secondly, there is the lay inspector, who lacks the basic training of the former but aspires to take up meat inspection as his career after obtaining a certificate of competence at some recognized technical school. Very obviously, the training of these two groups of potential meat inspectors must differ considerably in form and extent, but the purpose here is to refer to some general principles that must be observed wherever meat inspection is taught, and also to mention some specific aspects by which improvement in teaching could be secured.

The need for a greater measure of uniformity in meat-inspection teaching will not be questioned by those who have had the opportunity of investigating this aspect at the various schools. One of the reasons for training deficiencies in a number of schools is that the lecturers responsible, though admittedly well qualified theoretically, have not taken steps to acquire the essential practical knowledge that can be obtained in no other way than by experience in a large abattoir ; stress is laid on the size of the abattoir, for it is only in large establishments that a wide diversity of pathological conditions and abnormalities will be encountered. No person should be appointed to teach meat inspection, therefore, unless he can produce evidence of a fairly wide practical experience in the day-to-day problems that inevitably arise when large numbers of animals are slaughtered.

In certain countries in the Far East, during ante-mortem inspection of animals for slaughter it is a practice to reject any animal affected with mange, even though the bodily condition may give every indication that the animal would yield a useful and marketable carcass. The reasons advanced for such a decision cannot be other than unconvincing, but the frequency of the practice leads one to believe that such a judgement is generally taught, and that the teaching is therefore at fault and must be held responsible. Accordingly, it would seem wise to draw attention to certain shortcomings in the teaching of meat inspection and to make suggestions, based on a lengthy experience, as to how a greater measure of uniformity in teaching may be secured, thus bringing about a corresponding increase in the efficiency of the personnel engaged in such work. A number of recommendations are included here by which the interest of the student may be aroused and maintained, though one has yet to meet a student who did not wish to " run before he could walk " ; in other words, students aspire at once to study the problems of disease and it is at times difficult to curb or resist this desire. The lecturer must insist that in the earlier stages of tuition the student be encouraged to recognize the normal—whether it be a healthy animal, a carcass, or an organ that is in every way normal—and it is wise to avoid any reference to disease, except in the most general terms, until a thorough grounding in animal anatomy and physiology has been secured.

Ante-mortem Inspection

The value of the thermometer in ante-mortem inspection should be impressed on the student, and the necessity for taking the temperature of any animal unable to stand ; similarly, it should be stressed that a rise in temperature is usually associated with the onset of most communicable diseases. He may also be instructed on the position of the superficial lymph-nodes in cattle, though undue stress should not be attached to this because, although the submaxillary, prescapular, and precrural lymph-nodes can readily be palpated in the lean bovine animal, they furnish evidence of disease so rarely that their routine examination during ante-mortem inspection is scarcely justifiable.

Though it is unreasonable to expect a student to possess the detailed knowledge of the farmer as to the characteristics of a good butcher's animal, he should be acquainted with the salient features that constitute a desirable conformation. It is also wise to indicate that the butcher's practice of palpating the scrotum in castrated bovines furnishes a valuable indication as to the bodily condition of the animal, inasmuch as it is in this location that body fat is last to be deposited ; thus an animal with plentiful scrotal fat is likely to yield an attractive and well-nourished carcass.

Methods of Slaughter

A point frequently overlooked during teaching is that the stunning of an animal by any means prior to bleeding causes a brief but appreciable rise in the arterial blood-pressure of the animal, and that it is important that advantage be taken of this *vis a tergo* by severing the neck vessels immediately the animal has been stunned. Instruction should also be given that delay in bleeding is one of the factors responsible for the occurrence of " splashed " meat and that meat so affected, though sometimes unfit for sale in the form of retail joints, may safely and reasonably be used as an ingredient of manufactured foods.

Anatomy

In the study of anatomy the better-educated student possesses an advantage, for most of the terms used have a Greek or Latin derivation. Whenever possible this derivation should be explained, as, for example, the word " circumvallate ", which means " surrounded by a ditch ". There is, however, a tendency to inflict too much anatomical detail on

the student of meat inspection; it is unreasonable to require him to memorize the names and position of all the skeletal muscles of the animal body or the minor vessels of the circulatory system.

Once the student is thoroughly conversant with the framework of the animal body, he is in a position to study the various systems, and lectures on these subjects should be accompanied by numerous visits to the slaughterhouse, where experience can be gained in recognizing the various organs and their differential features in each of the food animals. It is also important that instruction be given as to how the shape and appearance of organs may differ in animals of the same species but of different ages. Thus, the spleen of the young bovine, with its rounded edges and reddish-brown colour, may be contrasted with that of the cow, with its sharp borders and greyish-blue colour of the surface. Similarly, the liver of the cow can usually be recognized by the presence of a well-marked " waist " between the left and right lobes. In demonstrating the digestive system there is no better method of impressing on the student the structure of the ruminant stomach than by inflating the organ, and in the case of the pig stomach to open the organ and demonstrate the region of the fundus, from which pepsin is obtained.

The recognition of the sex of an animal when in carcass form is important, and here teaching is often at fault, particularly in relation to the appearance of the external inguinal ring in the male bovine, sheep, and calf, and the disposition of the inguinal canal. In this respect it is advantageous to enlarge on the intra-abdominal position of the testicles in foetal life and to explain the mechanics of cryptorchidism, a condition frequently encountered in slaughterhouse work.

Students are often concerned as to why the kidneys of the bovine are lobulated whereas in the other animals the surface of the organs is smooth. It should be explained that in all the mammalia the kidneys have a lobulated structure in early embryonic life, but in all animals except the bovine the lobes eventually become fused to present a uniformly smooth surface. Perhaps the most illuminating demonstration that can be given in a slaughterhouse is on the nearly full-time foetal calf, with the fascinating inter-attachment of the maternal and foetal cotyledons and the course of the foetal circulation ; after such a demonstration the reason for the peculiar disposition of the lesions of tuberculosis in the congenitally-infected calf becomes readily apparent, as also does the etiology of pyosepticaemia neonatorum in calves. It always creates interest when lecturing on the female reproductive system to discuss the physiology of twins and free-martins, and the reasons for the occurrence of extra-uterine pregnancy.

When one comes to compare the teaching of meat inspection in various countries one finds that the greatest lack of uniformity is in the naming of the various lymph-nodes, and nothing could be more desirable than a

general agreement to adopt a standardized nomenclature. Quite apart from the need for uniformity in this respect, it is also desirable that there be more general agreement as to the accepted drainage-areas of particular nodes and that greater stress be laid on the fact that certain nodes are quite frequently absent. There is still divergence of opinion on the areas drained by such nodes as the prescapular (lymphoglandulae cervicalis superficialis) and precrural (lymphoglandulae subiliacus) of the ox, and on whether the precrural nodes do, in fact, drain the anterior quarters of the bovine udder. It should also be stressed that nodes such as the external iliacs (lymphoglandulae iliaci lateralis) and right bronchial (lymphoglandulae bifurcationis dexter) and some of the suprasternal group (lymphoglandulae mediastinales ventrales) are frequently absent in the bovine, though in the suprasternal group the largest and most constantly present is the one located in the fifth intercostal space. Numerous other cases could be cited where clarification and uniformity of teaching on the lymphatic system is required.

In considering the position of the lymph-nodes it is always advisable to give the student some instruction in how the carcasses of animals are divided into marketable retail joints. It is here that a firm grounding in knowledge of the skeletal system comes into play, and it is of the greatest practical importance that the student be able to expose and identify the lymph-node or nodes that may be present in an isolated joint of meat which may be presented for his inspection; one has seen acknowledged experts confused when confronted with specimens of meat in which it is desirable that the lymph-nodes should be incised. Students should therefore be required to demonstrate that they are able to expose every lymph-node in a carcass and its viscera, and should be expected to do this with reasonable dexterity and without causing excessive mutilation.

Pathology

As inflammation is the basis of all pathology it is wise to demonstrate the various types of inflammatory change that may be encountered in meat inspection. But, most important of all, it is essential that the student be taught to recognize and appreciate the macroscopic difference between an inflammatory change of the acute type and one which shows evidence of chronicity. In the past, the inability of meat-inspection personnel to recognize simple pathological conditions and to differentiate accurately between acute and chronic lesions, particularly in relation to tuberculosis, has resulted in untold amounts of meat being unnecessarily condemned and destroyed; it would be interesting to conjecture the number of occasions on which anaemic infarcts in the kidney of the cow have been

erroneously classified as lesions of tuberculosis. Though one would hesitate to minimize the potential danger of any systemic infection of the animal body, it should be pointed out that extensive pathological processes with the formation of pus, such as occur in traumatic pericarditis and pyometra, do not necessarily call for condemnation of a carcass, inasmuch as they are less likely to produce a generalized systemic infection than is usually supposed ; the judgement of all septic infections depends on whether or not the septic process has become generalized throughout the carcass.

Conclusions

No meat-inspection service can hope to operate efficiently unless the personnel conducting routine inspections, whether in the abattoir, the meat market, or elsewhere, have previously received an adequate period of theoretical and practical training. In order to achieve this it is essential that the teaching staff responsible are in possession of a thorough grounding in the basic sciences and are able not only to imbue the students with some of their enthusiasm but also to impart to them their own theoretical and practical knowledge. This study indicates some of the ways by which greater efficiency may be secured.

Part VII

MEAT-HYGIENE PRACTICE

SURVEY OF MEAT-HYGIENE PRACTICES IN EUROPE

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The World Health Organization has been active in the field of veterinary public health for a number of years now, and as far back as 1952 a questionnaire on the subject was sent out to member governments of the Organization's European Region.

In January 1954, a further questionnaire, confined to meat hygiene and public meat-inspection procedures, was sent out to the experts of the twenty countries of the same Region, who had been invited to attend the WHO/FAO Seminar on Meat Hygiene, planned for February 1954 in Copenhagen. The immediate object of the second questionnaire was to obtain background information that would serve as a useful adjunct to the discussions at the Seminar on the many and varied problems to be canvassed. Completed questionnaires were returned in respect of all the countries concerned.

Subsequent to the holding of the Seminar, the answers to the questionnaire were checked and officially confirmed by the respective governments. The following is a summary of these replies, in the preparation of which some effort has been made to tabulate and compare the information supplied. It has not proved possible to give all the detail, but the summary presents a fair general picture of the meat-hygiene practices now current in Europe. No attempt has been made to comment or to draw general conclusions, since the task of the Seminar was largely exploratory and the views of the participants on the various problems discussed are already covered in the earlier sections of this monograph.

National Legislation

The following are the authorities responsible for legislation concerning meat hygiene and meat inspection in the respective countries :

Country	*Authorities*
Austria	Federal Ministry of Agriculture and Forestry ; Federal Ministry for Social Administration
Belgium	Chamber of Representatives ; Senate
Denmark	Ministry of Agriculture
Finland	Ministry of Agriculture : Veterinary Department
France	Ministry of Agriculture
Germany	Government ; Federal Länder governments
Greece	Ministry of Agriculture
Ireland	Department of Agriculture ; Department of Health
Italy	High Commissariat for Public Health and Hygiene : General Directorate of Veterinary Services
Morocco	Administrative authorities, at the instance of Directorate of Agriculture, Veterinary Department of the Stock-Breeding Service ; municipalities
Netherlands	Ministry of Social Affairs and Public Health ; Ministry of Agriculture ; municipalities
Norway	Ministry of Agriculture : Veterinary Directorate ; Ministry of Social Affairs
Portugal	Ministry of Economy : General Directorate of Veterinary Services
Spain	General Directorate of Health : Inspectorate-General of Veterinary Health
Sweden	Home Department ; Department of Agriculture ; Royal Medical Board ; Royal Veterinary Board
Switzerland	Federal Council
Tunisia	Presidency of the Council ; Ministry of Agriculture ; Ministry of Trade ; Ministry of Public Health
Turkey	Department of Agriculture : General Directorate of Veterinary Affairs ; Department of Public Health
United Kingdom :	
England and Wales	Ministry of Food ; Ministry of Health
Scotland	Department of Health
Yugoslavia	Secretary of State for Agriculture ; Federal Public Health Office

Meat Inspection and Supervision of Premises

The following are the authorities responsible at the national and the local levels for the maintenance of meat inspection and the supervision of premises where meat and meat products are stored, processed, and/or sold :

Country	*Authorities* *national*	*local*
Austria	Federal Ministry of Agriculture and Forestry ; Federal Ministry for Social Administration	Provincial governments ; district administrations ; municipalities

Country	Authorities: national	Authorities: local
Belgium	Ministère de la Santé publique et de la Famille	Burgomasters or their nominees
Denmark	Veterinary Service : Meat Inspection Division ; Ministry of Agriculture ; local health authorities	
Finland	Ministry of Agriculture : Veterinary Department	
France	Ministry of Agriculture : Veterinary Services	Mayor of each commune
Germany	Federal Government	Länder governments
Greece	Veterinary officers of prefectures, of provinces, of veterinary aid hospitals, and of the veterinary police	
Ireland	Department of Agriculture (production for export)	Local authorities under Department of Agriculture (production for home consumption)
Italy	High Commissariat for Public Health and Hygiene	Prefects of provinces ; mayors of communes
Morocco	Chief, Stock-Breeding Service ; Chief Inspector, Meat Department ; municipal veterinary inspectors ; veterinary officers of the Stock-Breeding Service ; public-health officers	
Netherlands	Ministry of Social Affairs and Public Health : Veterinary Inspection Service	Municipalities
Norway	Ministry of Agriculture : Veterinary Directorate	Local health boards under the Directorate of Health
Portugal	Ministry of Economy : General Directorate of Veterinary Services	Municipal communes, under General Directorate of Civil and Political Administration, Ministry of the Interior
Spain	Provincial and municipal veterinary inspectors under the Health Service	
Sweden	Royal Veterinary Board	Provincial governments ; municipal health boards
Switzerland	Cantonal governments	Local sanitary authorities
Tunisia	Ministry of State ; Ministry of Agriculture ; Ministry of Trade	Municipalities and local authorities
Turkey	Department of Agriculture : General Directorate of Veterinary Affairs	
United Kingdom :		
England and Wales	Ministry of Food ; Ministry of Health	Local authorities
Scotland	Department of Health	Local authorities
Yugoslavia	Veterinary Services	Municipalities and local authorities

Sale of Meat and Meat Products

In most of the countries covered by the survey, it is not permissible to sell for human consumption meat or meat products that have not been submitted to official meat inspection. Finland makes an exception for areas of sparse population. Because of the shortage of veterinarians in Greece, outlying villages and small towns are exempted, but a medical officer is assigned the task of inspecting meat products, fresh or canned fish, etc., in these parts.

The position in Ireland is the following. In a number of urban areas the sale of meat which has not been officially inspected is prohibited under by-laws made by the local authorities concerned. In areas in which meat inspection by-laws are not in force, it is permissible to sell meat which has not been officially inspected, but the local authorities concerned arrange as far as practicable for the inspection of all such meat and meat products. All fresh meat and open, packed meat products intended for export, and all bacon and all meat for canning whether for export or for home consumption, are subjected to inspection by officers of the Department of Agriculture.

In Norway meat for human consumption must be subjected to official inspection prior to sale in all towns of more than 2000 inhabitants; a similar requirement in respect of rural districts may be prescribed at the discretion of the Ministry of Agriculture. In Sweden, meat inspection is obligatory in every town, and in communes of 4000 inhabitants and over. It may be made compulsory on request of the local authority by resolution of the provincial government. At the present time more than 50% of communes throughout the country have obligatory meat inspection. In Tunisia, an exception is made in respect of slaughterings authorized by local regulation on the occasion of certain religious festivals and ceremonies.

As regards the United Kingdom, in England and Wales the business of slaughtering animals for sale for human consumption cannot be carried on except at recognized slaughterhouses. Local authorities are responsible for meat-inspection arrangements, and notification of slaughter of an animal for sale for human consumption must be delivered to the local authority. If meat is not inspected within a certain time after slaughter, it may be removed and sold, provided there is no suspicion of disease. It is an offence to sell meat unfit for human food. Meat is inspected at the slaughterhouse in accordance with the methods and criteria contained in a memorandum issued by the Ministry of Food.* In Scotland local

* Great Britain, Ministry of Food (1952) *Memorandum regarding the methods and criteria of meat inspection recommended by the Ministry of Food for adoption by local authorities*, London (Memo. 3/Meat)

authorities are required to make arrangements for the inspection of the carcasses of all animals killed at slaughterhouses, and the business of slaughtering animals for sale cannot be carried on except at recognized slaughterhouses.

Food Animals

The term " food animals ", as used in the meat-inspection legislation of the respective countries, embraces the following:

Country	*Food Animals*
Austria	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses, donkeys, and mules
	Buffaloes
Belgium	Cattle
	Calves
	Pigs
	Sheep and goats
Denmark	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses
Finland	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses
France	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses, donkeys, and mules
Germany	Cattle
	Calves
	Pigs
	Sheep and goats
	Single-hoofed animals
Greece	Cattle
	Calves
	Pigs
	Sheep and goats
Ireland	Cattle
	Calves
Ireland (*continued*)	Pigs
	Sheep and goats
	Poultry
Italy	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses, donkeys, and mules
Morocco	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses, donkeys, and mules
	Camels
Netherlands	Cattle
	Calves
	Pigs
	Sheep and goats
	Single-hoofed animals
Norway	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses
	Reindeer, elks, red deer, roe deer, and fallow deer
	Bears
	Whales
Portugal	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses and mules
Spain	Cattle
	Calves
	Pigs
	Sheep and goats

Country	*Food Animals*
Sweden	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses
	Elks and reindeer
Switzerland	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses
Tunisia	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses
	Camels
Turkey	Cattle
	Calves
	Sheep and goats
	Water buffaloes
	Camels
United Kingdom	Cattle
	Calves
	Pigs
	Sheep and goats
	Horses, donkeys, and mules
Yugoslavia	Cattle
	Calves
	Pigs
	Sheep and goats
	Single-hoofed animals
	Buffaloes

Food Animals Slaughtered

The approximate numbers of food animals slaughtered annually in the respective countries are given in the following table :

NUMBER OF FOOD ANIMALS SLAUGHTERED

Country	Cattle	Calves	Pigs	Sheep and goats	Horses, donkeys, and mules	Other animals
Austria	328 891	471 020	1 334 852	41 753	26 440	—
Belgium	552 637	266 658	2 088 908	97 789	59 370	—
Denmark	400 000	700 000	5 000 000	50 000	20 000	—
Finland	507 871	304 561	329 226	203 110	29 297	—
France (1954)	2 875 524	5 358 484	6 584 044	5 054 677	316 900	—
Germany	2 584 500	2 700 000	14 500 000	754 400	123 500	—
Greece	130 000	120 000	100 000	2 650 000	—	—
Ireland	400 000	12 000	1 000 000	700 000	—	—
Italy	905 200	670 355	1 757 153	3 346 316	163 236[a]	—
Morocco	259 462		64 132	1 098 885	12 599	13 196[b]
Netherlands (1952)	528 000	757 000	2 000 000	92 000	37 000	—
Norway	183 114	182 113	326 126	453 741	9 282	1 615 518
Portugal	115 361	123 233	434 045	1 260 123	4 721	—
Spain	200 000	700 000	250 000	4 400 000	40 000	—
Sweden	350 000	950 000	1 500 000	140 000	40 000	5 500[c]
Switzerland (1954)	258 001	514 957	901 905	116 122	13 702	—
Tunisia	61 900	12 000 to 15 000	9 000 to 10 000	350 000 to 400 000	8 000 to 9 000	1 500 to 2 000[b]
Turkey	302 566	62 921	2 200	3 490 608	—	19 376[d]
United Kingdom	2 102 919	1 097 284	2 068 604	7 499 164[e]	55 000	—
Yugoslavia	318 254	262 208	620 203	322 705	7 629	3 088[f]

[a] Horses only
[b] Camels
[c] Elk and reindeer
[d] Water buffaloes (18 441) and camels (935)
[e] Sheep only
[f] Buffaloes

Ante-mortem Inspection

Ante-mortem examination of food animals intended for commercial slaughter is obligatory by law in most of the countries covered by the survey. Finland makes an exception of sparsely populated areas. In Ireland, it is obligatory in respect of cattle, sheep, and pigs slaughtered for export or for canning, and of all pigs intended for curing; as far as practicable local authorities arrange for ante-mortem inspection of food animals for sale for home consumption. In Morocco, although not obligatory by law, ante-mortem inspection is nevertheless carried out in practice in the slaughterhouses of the large urban centres where municipal by-laws require animals to be kept under observation for 24 hours prior to slaughter.

In Norway, regulations apply only to officially approved slaughterhouses and to establishments where animals are slaughtered for export. Sweden's legislation embraces all towns and communes of 4000 inhabitants or over. Although not at present obligatory in the United Kingdom, ante-mortem examination is carried out at many slaughterhouses; it is proposed to include obligatory ante-mortem examination in the revised regulations for Scotland.

In all the countries concerned except the United Kingdom, ante-mortem inspection is normally carried out by qualified veterinarians. In Austria, Tunisia, Switzerland, and Yugoslavia, specially trained lay personnel are also employed in this work—in the two last-mentioned countries, generally only in areas without veterinarians. Lay personnel are also used, under veterinary supervision, in France, Ireland, Morocco, and the Netherlands. In France and the Netherlands, veterinarians retain responsibility. In Germany, where the requisite veterinary surgeons are not available, lay personnel with prescribed qualifications may be appointed to carry out this inspection. The lay inspectors may not function where local provisions stipulate the services of a veterinary surgeon for the purpose. Health officers may be assigned to this work in Portugal and in Tunisia.

Post-mortem Inspection

In all the countries surveyed, post-mortem examination of animals slaughtered for commercial purposes is obligatory by law, with the exception of Ireland, and part of the United Kingdom (England and Wales). The requirement is obligatory in Ireland in the case of (*a*) all cattle, sheep, and pigs intended for export or for canning; (*b*) all pigs intended for curing as bacon; and (*c*) all animals slaughtered for human consumption

in urban districts in which meat inspection by-laws are in force. Finland and Norway make an exception of sparsely populated areas ; Norwegian regulations apply to towns of more than 2000 inhabitants and to officially approved slaughterhouses and establishments where animals are slaughtered for export. Tunisia makes an exception in respect of slaughterings authorized by local regulation on the occasion of certain religious festivals and ceremonies. In England and Wales, although this is not yet a statutory requirement, meat is inspected at the slaughterhouse in accordance with the methods and criteria recommended by the Ministry of Food.*

The same types of staff are used for post-mortem inspection in the various countries as carry out the ante-mortem examination of slaughter animals. In Germany, the lay inspectors may give independent judgement of meat quality only in the case of animals examined by them prior to slaughter, with the further proviso that no essential parts have been removed from the carcass and that no defects other than of an insignificant and purely local nature have been found. In Morocco and Tunisia, health officers may be specially designated for this purpose. In the part of the United Kingdom where post-mortem examination is obligatory (Scotland), the routine work is done by " detention officers " with authority to detain carcasses for examination by " meat inspectors " who are veterinarians.

Meat-Inspection Staff

The following are the authorities in the respective countries which directly employ the meat-inspection staff:

Country	*Authorities*
Austria	Municipalities
Belgium	Government ; municipalities
Denmark	Ministry of Agriculture ; municipalities
Finland	Ministry of Agriculture : Veterinary Department
France	Ministry of Agriculture (industrial establishments) ; mayor of each commune (public slaughterhouses)
Germany	District authorities
Greece	Ministry of Agriculture : Directorate of Veterinary Service
Ireland	Department of Agriculture ; local authorities
Italy	Mayor of each commune

* Great Britain, Ministry of Food (1952) *Memorandum regarding the methods and criteria of meat inspection recommended by the Ministry of Food for adoption by local authorities*, London (Memo. 3/Meat)

Country	*Authorities*
Morocco	Directorate of Veterinary Service ; Directorate of the Interior ; or Directorate of Agriculture
Netherlands	Municipalities
Norway	Municipal authorities under the Ministry of Agriculture
Portugal	Municipalities
Spain	Inspectorate General of Veterinary Health ; Ministry of Health
Sweden	Royal Veterinary Board ; local authorities
Switzerland	Local health boards or cantonal authorities
Tunisia	Municipalities
Turkey	Municipal inspectors, certified and approved by the General Directorate of Veterinary Affairs
United Kingdom	Local authorities
Yugoslavia	Municipalities

The tabulation below gives the approximate numbers of personnel employed in public meat inspection in the various countries :

Country	*Veterinarians* *whole-time*	*Veterinarians* *part-time*	*Specially trained lay personnel*	*Other personnel*
Austria	54	900	1 000	—
Belgium	41	109	—	—
Denmark	150	750	—	225
Finland	22	80	—	—
France	200	2 800	400	1 per commune (in principle)
Germany	1 000	4 000	2 000	—
Greece	10	80	—	—
Ireland	68	155	37	54
Italy	3 000 (municipal veterinarians)	—	—	—
Morocco	16	54	50	—
Netherlands	154	154	600	—
Norway	41	52	—	—
Portugal	12	219	—	52
Spain	—	4 000	—	—
Sweden	93	150	250 (technicians for trichinosis examination)	250
Switzerland	50	535	2 500	—
Tunisia	3	19	25	8
Turkey	97	342	—	—
United Kingdom :				
England and Wales	20	10	2 700	—
Scotland	6	60-65	100	74
Yugoslavia	36	400	60	—

Stunning before Slaughter

Stunning of food animals prior to slaughter is compulsory by law in all the countries surveyed except France, Greece, Morocco, Portugal, Tunisia, and Turkey. In France, there may be local regulations in the matter, but no national legislation exists. Ireland makes an exception in respect of pigs. In Italy, ritual slaughter in accordance with religious customs may be practised, provided it conforms in every respect to the rituals concerned. In Switzerland, legislation prescribing pre-slaughter stunning was first passed in 1896. In Morocco and Tunisia, Jewish and Moslem rites are practised in the slaughter of food animals, and in Turkey stunning prior to slaughter is forbidden by religious custom. The United Kingdom makes an exception for Jewish and Moslem slaughter.

The following are the methods of stunning in use in the various countries:

Country	*Methods*	
Austria	Captive-bolt pistol	
	Electrical stunning	
Belgium	Small animals:	felling
	Big animals:	captive-bolt pistol
	Pigs:	electrical stunning
Denmark	Small animals:	felling
	Big animals:	pistol
	Pigs:	pistol
		CO_2 stunning
		electrical stunning
Finland	Felling	
	Captive-bolt pistol	
	Electrical stunning (pigs)	
France	Electrical stunning	
Germany	Felling (animals not over 2 years old)	
	Electrical stunning	
Greece	—	
Ireland	Captive-bolt pistol	
	Electrical stunning	
Italy	Pithing	
	Bolt pistol	
	Any other method recognized by the prefects of the provinces on the advice of the provincial health boards	
Morocco	Bolt pistol (municipal slaughterhouses)	
	Electrical stunning (pigs, in industrial establishments)	
Netherlands	Felling	
	Pistol	
	Electrical stunning	

Country	*Methods*
Norway	Felling Pistol Electrical stunning
Portugal	Pithing Pistol (single-hoofed animals) Electrical stunning (pigs)
Spain	Pithing
Sweden	Felling Pistol Electrical stunning
Switzerland	Felling Pistol Electrical stunning
Tunisia	Felling (horses and pigs)
Turkey	—
United Kingdom	Captive-bolt pistol Free-bullet gun (mostly used on horses) Electrical stunning
Yugoslavia	Felling Pistol (Schermer) Electrical stunning

Bacteriological Examination

A bacteriological examination of carcasses and organs is required by law in certain cases in all the countries except Italy, Morocco, Spain, Tunisia, and the United Kingdom. Italy, although not prescribing it by law, advises the use of this additional aid to meat judgement. In Morocco, although again not a statutory requirement, bacteriological examination is in current use, at the discretion of the veterinary inspector. Bacteriological examination is not in general use in Spain. In Tunisia, municipal veterinary officers may order an examination of this kind where septicaemia is suspected. In Turkey, it is used when the veterinary inspector desires evidence for establishing a diagnosis.

Country	*Cases in which bacteriological examination is required*
Austria	Septicaemia Emergency slaughter Emergency slaughter of horses on account of colic Carcasses where evisceration was not carried out immediately after slaughter Carcasses where organ important for judging the meat was removed prior to examination

Country	*Cases in which bacteriological examination is required*
Austria (*continued*)	Carcasses where important organ was subjected to treatment not in conformity with regulations
Belgium	Colic Metritis Enteritis Peritonitis, diffuse Mastitis Accident, where cause undetermined
Denmark	Emergency slaughter, excluding as causes recent traumatic lesions to head, neck, or legs Presence of disease, where carcass is in condition not automatically requiring total condemnation, but where risk of generalized bacterial infection may exist
Finland	When general health condition of animal, anamnesis, or anatomo-pathological changes indicate danger of generalized infection (blood infection), but the changes which have occurred in the meat and organs are not sufficiently great to warrant condemnation without further examination
France	Emergency slaughter due to illness or accident Diseases of the digestive system Diseases of the genital system
Germany	Emergency slaughter, excluding as causes bone fractures and external injuries where animal is slaughtered at once Basic change in general physical condition Suspected blood-poisoning or presence of meat-poisoning agents (possible causes : inflammation of intestine, udder, uterus, joint and hoofs, navel, lungs, pleura, and peritoneum)
Greece	Emergency slaughter Suspected microbial diseases
Ireland	Septicaemia Pyaemia Neoplasms Food-poisoning conditions Any obscure condition not otherwise readily diagnosable } Examination at discretion of veterinary officer
Italy	Advised, conditions not stated
Morocco	Any carcass examined at discretion of veterinary inspector
Netherlands	Swine fever Haemorrhagic septicaemia in cattle Gangrenous coryza in cattle Inflammation in internal organs Septicaemia Toxaemia Pyaemia Gangrenous mastitis

Country	*Cases in which bacteriological examination is required*
Netherlands (*continued*)	Peritonitis, caused by injury to the stomach, intestines, or uterus
	Haemoglobinaemia
	Carcasses where slight evidence of disease after slaughter is not consistent with serious symptoms noted *ante mortem*
	Emergency slaughter
	Animals dying in exceptional circumstances where condemnation is not prescribable
	Swine erysipelas
	Haemorrhagic septicaemia in swine
	Septic pleuropneumonia in calves
	Influenza in horses
	Adenitis in horses
	Necrotic stomatitis
	Grass tetany
	Epizootic aphthae
	Tetanus
	Paratuberculous enteritis
	Piroplasmosis
	Puerperal paresis
	Pyogenic mastitis
	Traumatic pericarditis
	Retention of secundines
Norway	Chronic pasteurellosis
	Swine erysipelas
	Paratuberculosis
	Traumatic indigestion
	Chronic metritis
	Chronic pleuropneumonia
	Retention of secundines
	Gastro-enteritis
	Chronic catarrh
	Ascites
	Mastitis, catarrhal and purulent
	Emergency slaughter
	Any other carcass examined at discretion of meat inspector
Portugal	Hydraemia, in carcasses apparently otherwise in good condition
	Carcasses of animals used for preparation of sera and vaccines, and subsequently accepted for slaughter under prescribed conditions
	Any other carcass examined at discretion of meat inspector
Spain	—
Sweden	Suspected disease
	Suspected septicaemia
	Emergency slaughter
	Carcasses where signs of disease or of abnormal weakness were detected during ante-mortem inspection
	Carcasses where condition of organs indicates reduced power of resistance to disease
	Carcasses of size or general condition indicating unsoundness

Country	*Cases in which bacteriological examination is required*
Switzerland	Any carcass examined at discretion of meat inspector
Tunisia	Discretionary where septicaemia suspected
Turkey	Any carcass examined at discretion of meat inspector
United Kingdom	Any carcass examined at discretion of meat inspector
Yugoslavia	Suspected presence of *Salmonella* and : (*a*) evidence of serious illness prior to slaughter (*b*) slaughter on account of enteritis, mastitis, endometritis, arthritis, tendonitis, paronychia, pododermatitis, umbilical infection, pneumonia, pleurisy, or suppurant or putrid wounds (*c*) slaughter on account of serious illness, excluding as causes foot-and-mouth disease or glanders, unaccompanied by complications; pleuropneumonia, contagious, in cattle; sheep-pox; swine erysipelas; swine plague; encephalomyelitis, infectious, in pigs; fractures, external wounds (wounds, bruises, etc.), or other conditions caused by foreign bodies (obstruction of oesophagus), prolapse of uterus, bladder, or rectum, where the animal is slaughtered immediately upon onset of the disease and prior to appearance of complications (fever, etc.) (*d*) where viscera were not removed immediately upon slaughter or death of the animal (*e*) where organs essential for judging the meat have been removed or so treated as to make judgement impossible (*f*) where, in absence of ante-mortem inspection, cause of slaughter cannot be ascertained (*g*) where, in apparently sound animals, the presence of *Salmonella* is detected after slaughter (*h*) any other cause rendering the meat harmful to human health

Examination of Pigs for Trichinosis

Examination of pigs for trichinosis is compulsory in Germany, Greece, Italy, Norway, Portugal, Spain, Sweden, Turkey, and Yugoslavia; i.e., in slightly less than half the number of countries covered by the survey. It is also compulsory in Austria in respect of pork intended for consumption raw or for the preparation of raw meat products. In Belgium, pork may be subjected to examination, at the discretion of the Ministère de la Santé publique et de la Famille. Denmark requires this examination for boars and sows, and for pigs over 100 kg in dead weight. In Finland, it is obligatory in slaughterhouses and in respect of export or import animals. In France and Switzerland, too, imported pork is sometimes examined for

this condition ; the domestic production is assumed to be free from the disease. No *Trichinella* infestation has been recorded in Ireland ; periodic checks are made. Italy reports that, although examination for trichinosis is compulsory, the disease has not been found in that country. There is no special legislation on this item in Morocco, but general regulations regarding the wholesomeness of meat make examination for trichinosis compulsory. It is reported that no case of trichinosis in pig, rodent, or man has ever been recorded in Morocco. In the Netherlands, examination for trichinosis is required only for imported pork originating in countries of known infection. Tunisia is assumed to be free from the disease and, hence, examination is not compulsory. No special examination is prescribed in the United Kingdom, but trichinosis is one of the diseases looked for in the course of general examination.

The following are the examination methods in use :

Country	*Methods*
Austria	Trichinoscope (Reissmann method)
Belgium	Trichinoscope
Denmark	Trichinoscope Microscope
Finland	Trichinoscope Microscope
France	Trichinoscope
Germany	Trichinoscope Microscope
Greece	Trichinoscope Microscope
Ireland	Microscope
Italy	Trichinoscope
Morocco	Trichinoscope
Netherlands	Microscope Trichinoscope
Norway	Trichinoscope
Portugal	Trichinoscope Splender digestive method, in laboratories
Spain	Trichinoscope Microscope
Sweden	Microscope
Switzerland	Trichinoscope
Tunisia	Method selected by the veterinarian
Turkey	Trichinoscope
Yugoslavia	Trichinoscope

Specially trained lay personnel may carry out this examination in Austria, Belgium, Denmark, Finland, Germany, Greece, Netherlands, Norway, Sweden, Switzerland, Tunisia, and Yugoslavia.

Diseases or Conditions entailing Total Condemnation of Carcasses

Country	*Categories*
Austria	Abnormal odour, associated with urine or sexual organs Anthrax Anthrax, symptomatic (blackleg) Carcasses of animals dying from natural causes ; carcasses of unborn or stillborn animals

Country	*Categories*
Austria (*continued*)	Cattle plague
	Decomposition and putrefaction: general
	Dropsy, acute and still ascertainable 24 hours after slaughter
	Emaciation, extreme, due to disease
	Glanders
	Jaundice, where carcasses show discoloration 24 hours after slaughter
	Rabies
	Sarcocysts, generalized
	Septicaemia, accompanied by substantial visible tissue changes
	Septicaemia, haemorrhagic, in cattle
	Sheep-pox
	Tetanus
	Tumours, multiple
Belgium	Abnormal appearance, colour, texture, or taste in any carcass
	Actinomycosis, generalized
	Anasarca
	Anthrax, bacterial
	Anthrax, symptomatic (blackleg)
	Aspergillosis, generalized
	Botryomycosis, generalized
	Bruising, extensive
	Carcasses of:
	(*a*) animals dying from natural causes
	(*b*) animals the meat of which is sanguinary
	(*c*) animals eviscerated with undue delay
	(*d*) animals poisoned by toxic substances
	(*e*) animals given certain medicaments capable of causing abnormal odour in the meat
	(*f*) unborn animals; stillborn animals, in certain cases
	Cattle plague
	Coryza, gangrenous, in cattle
	Emaciation
	Enteritis, infectious, in young animals
	Generalized infiltration of the tissue, with or without cavitary transudation
	Glanders
	Inflammation, gangrenous, in one or more organs
	Jaundice
	Lymphadenitis, generalized
	Meat containing:
	(*a*) *Salmonella* and coliform bacteria
	(*b*) asporulate and anaerobic bacteria
	(*c*) multiple bacteria, whether or not commonplace
	Metritis, acute
	Omphalophlebitis
	Pleuropneumonia, septic, in young animals, accompanied by changes in the tissue or parenchyma
	Polyarthritis, in young animals
	Putrefaction, confirmed or imminent

Country	*Categories*
Belgium (*continued*)	Pyaemia Rabies or suspected rabies Septicaemia Septicaemia, gangrenous Sheep-pox Tetanus Trichinosis Tumours, multiple, in muscular tissue, bones, or lymph-nodes *Salmonella* diseases in the horse
Denmark	All infectious and parasitic diseases generalized or prejudicial to health of animal Auto-intoxication Carcasses showing: (*a*) evidence of disease prejudicial to health of animal (*b*) local tissue-changes or lesions incapable of excision and prejudicial to health of animal Certain infectious and parasitic diseases (officially listed) transmissible to man (see Annex 12, page 420) Poisoning, acute and chronic, with secondary changes Tumours, generalized
Finland	Contagious animal diseases, dangerous (officially listed); other generalized infections (acute septic mastitis, metritis, pneumonia, etc.) *Cysticercus bovis*: more severe cases *Cysticercus cellulosae* Degeneration, noticeable, in musculature Distinct odour or taste, associated with urine or sexual organs; other distinct abnormal odours Emaciation, pathological Jaundice Lymphadenitis, noticeable Trichinosis Tuberculosis: certain kinds
France	Carcasses of cattle, pigs, horses, donkeys, and mules showing: (*a*) acute miliary tuberculosis, generalized (*b*) caseous tuberculosis, characterized by softening throughout considerable areas or affecting several organs (*c*) diffuse caseous tuberculosis, accompanied by lesions in the lymph-nodes and spreading caseation Carcasses of animals recognized to be suffering from tuberculosis of types other than those named above
Germany	Abnormal odour, associated with urine or sexual organs Anthrax Anthrax, symptomatic (blackleg) Blood poisoning Cattle plague Cysticerci in hogs Decomposition and putrefaction: advanced

Country	*Categories*
Germany (*continued*)	Dropsy, general, acute Emaciation, advanced, due to disease Glanders Presence of meat-poisoning agents Rabies Septicaemia, haemorrhagic, in cattle Swelling, multiple Trichinae in pigs, bears, cats, foxes, and carnivorous animals other than those named
Greece	Abnormal odour, colour, appearance, taste, or texture; in general, where sterilized meat retains such odour or taste for 24 hours after slaughter Anthrax, haematic Anthrax, symptomatic (blackleg) Cachexia, accompanied by marked emaciation Carcasses of: (*a*) animals dying from natural causes (*b*) animals slaughtered in emergency (*c*) animals eviscerated with undue delay (*d*) stillborn animals Cattle plague Cysticercosis, sarcosporidiosis, trichinosis Haemorrhages or congestion Hydraemia, where tissue continues to hold the water 24 hours after slaughter Jaundice, where meat retains discoloration for 24 hours after slaughter or an unpleasant taste or odour after sterilization Lymphadenitis, generalized Pleuropneumonia, contagious, in cattle and goats Pleuropneumonia, septic and contagious, in young animals: accompanied by anatomo-pathological lesions Putrefaction or impending putrefaction Rabies Septicaemia, pyaemia, presence of pathogenic organisms of the *Salmonella* group: in suspect animals; animals slaughtered in emergency; animals showing acute inflammation in the intestines, udder, uterus, joints, tendons, hoof, navel, lungs, pleura, peritoneum; animals with purulent or gangrenous sores Sheep-pox, and vaccinia in goats: acute Swine erysipelas, accompanied by visible lesions in tissue and fat Tuberculosis, accompanied by marked emaciation Tuberculosis, generalized in musculature Tumours, multiple and metastatic, in musculature, bones, or lymph-nodes
Ireland	Actinomycosis, generalized Anaemia, if pronounced Anthrax

Country	*Categories*
Ireland (*continued*)	Bruising, extensive and severe, with or without gangrene Decomposition Emaciation, pathological Fever Immaturity Jaundice Lymphadenitis, caseous, generalized Malignant catarrh Malignant neoplasms, unless localized in one organ Mastitis, acute and septic or gangrenous Measly pork Melanosis, generalized; any generalized pigmentation Metritis, acute and septic Odour, associated with disease or otherwise prejudicial to health Pericarditis, septic Pneumonia, septic or gangrenous Pyaemia, including "joint-ill" Rickets with malnutrition Sarcocysts, if generalized in the musculature and visible to the naked eye Septicaemia or septic intoxications Swine erysipelas, acute Swine fever Tetanus Trichinosis Tumours, multiple, in the musculature Uraemia: insufficient bleeding or any other condition of a morbid or pathological nature rendering the carcass unsightly, unwholesome, or unfit for human consumption
Italy	Carcasses totally condemned in cases of: (*a*) single-hoofed animals dying or slaughtered in emergency on account of diseases of the digestive system (*b*) tuberculosis in any form or stage in over-emaciated animals (*c*) trichinosis Slaughter is prohibited of animals suffering from or suspected to be suffering from: (*a*) anthrax (*b*) anthrax, symptomatic (blackleg) (*c*) cattle plague (*d*) gangrene, emphysematous (*e*) glanders (*f*) pleuropneumonia, infectious (*g*) rabies
Morocco	Cachexia, hydraemic: jaundice, fevers Cysticercosis, generalized Pyaemia: streptococcal, staphylococcal Septicaemia: anthrax, salmonellosis, etc.

Country	*Categories*
Morocco (*continued*)	Tuberculosis, not confined to a single visceral cavity, whether thoracic or abdominal, and affecting more than one lymph-node
Netherlands	Abnormal odour, colour, taste, or texture Anthrax Cachexia and hydraemia : severe Carcasses : (*a*) of animals dying from natural causes (*b*) insufficiently bled (*c*) showing *Salmonella* in one or more organs or in the musculature (*d*) where other pathogenic bacteria are found in musculature by bacteriological examination (sterilization is permissible in the case of swine erysipelas or contagious pneumonic bacilli in pigs) Cattle plague Cysticercosis, sarcosporidiosis, or trichinosis, where large numbers of the parasites are found Emergency slaughter for serious conditions Gangrene, emphysematous Glanders Morbus maculosus in horses Oedema, malignant Rabies Sheep-pox Tuberculosis, accompanied by hydraemia or cachexia Tumours : actinomycosis, botryomycosis, leukaemia, pseudoleukaemia : severe Any disease, other than those mentioned above, for which bacteriological examination is prescribed, where the musculature and/or adjoining tissue is severely affected
Norway	Adenitis in horses Anaemia, infectious, in horses Anthrax Cachexia Carcasses where bacteriological examinations are positive Cattle plague Coccidiosis and septic enteritis Coryza, gangrenous Croup Diphtheria in calves Dysentery Foot-and-mouth disease Gangrene, emphysematous Gastromycosis Glanders Leukaemia Milk fever Morbus maculosus Oedema, malignant

Country	*Categories*
Norway (*continued*)	Piroplasmosis in cattle
	Pleuropneumonia, contagious, in cattle and horses
	Poisoning, acute
	Pyaemia and septicaemia
	Rabies
	Salmonellosis in pigs
	Septicaemia, haemorrhagic, in cattle
	Smallpox and scabies in sheep
	Swine plague
	Tetanus
	Uraemia and haemoglobinuria
Portugal	Abnormal retention of secundines
	Anasarca
	Anthrax
	Anthrax, symptomatic (blackleg)
	Cattle plague
	Claudication in new-born animals
	Colibacillosis in calves
	Coryza, gangrenous, in cattle
	Dourine
	Encephalomyelitis, infectious, in horses
	Endocarditis, septic
	Enteritis, *Salmonella*, in cattle
	Enteritis, septicaemic, in calves
	Glanders
	Mastitis, gangrenous, in ewes
	Mastitis, infectious, in cows
	Metritis, purulent and septic
	Omphalophlebitis, suppurant
	Osteopyelitis, suppurant
	Pericarditis, traumatic and septic
	Peritonitis, septic
	Pneumonia, septic, in calves
	Polyarthritis, infectious, in young animals
	Pseudotuberculosis
	Pyaemia
	Pyaemia due to swine plague or bronchopneumonia in new-born animals
	Pyelonephritis, bacterial, in cattle
	Rabies or suspected rabies
	Salmonellosis in pigs and in horses
	Septicaemia, gangrenous
	Swine erysipelas
	Swine plague
	Tetanus
Spain	Actinomycosis
	Botryomycosis
	Anthrax
	Anthrax, symptomatic (blackleg)
	Cattle plague

Country	*Categories*
Spain (*continued*)	Coryza, gangrenous
	Dermatitis, pustular
	Diarrhoea, infectious
	Dourine
	Emaciation, abnormal
	Foot-and-mouth disease
	Glanders
	Lymphadenitis, epizootic
	Lymphadenitis, ulcerous, in horses
	Malta fever
	Mastitis, gangrenous, in ewes
	Meat poisoning
	Omphalophlebitis, suppurant
	Pasteurellosis
	Plague, diphtheria, cholera, and tuberculosis in birds
	Pleuropneumonia, contagious
	Polyarthritis, infectious
	Pseudotuberculosis in sheep and calves
	Purulent (pyogenic) infection
	Rabies
	Salmonellosis in horses
	Scrofula in oxen
	Septicaemia, gangrenous
	Septicaemia, haemorrhagic, sub-acute
	Smallpox
	Strangles, in single-hoofed animals
	Swine erysipelas
	Swine plague
	Tetanus
	Trichinosis
	Tuberculosis
	Unsightliness of meat
Sweden	Abnormal odour, pronouced
	Anthrax
	Cattle plague
	Cysticercosis, trichinosis, sarcocysts : in certain cases
	Degeneration, severe, in musculature
	Emaciation
	Emphysema, infectious
	Foot-and-mouth disease
	Glanders
	Jaundice
	Neoplasms, extensive, in musculature
	Oedema, generalized
	Oedema, malignant
	Pleuropneumonia, contagious, in cattle
	Rabies
	Septicaemia
	Swine fever
	Tuberculosis : in certain cases
	Variola, ovine

...ntry	*Categories*
...erland	Any meat, whether in raw or processed state, representing a possible danger to human health or of appearance or texture so repugnant as to preclude its use for human consumption
	Anaemia, serious
	Anasarca
	Anthrax
	Anthrax, symptomatic (blackleg)
	Cachexia, animal, advanced, resulting from disease
	Cattle plague
	Cysticercosis, noxious, in cattle, sheep, goats, or pigs, where the meat is aqueous or discoloured or where more than one parasite, dead or alive, is found in the majority of the muscle-cuts of the size of the palm of the hand
	Dropsy, generalized
	Dysentery in calves
	Erysipelas or pneumo-enteritis in pigs, or swine plague, generalized, or accompanied by pronounced cachexia
	Gas gangrene
	Glanders
	Inflammation of udder, matrix, joints, tendons, hoofs, navel, lungs, pleura, peritoneum, stomach, intestines, liver, and kidneys; specifically:
	(*a*) extensive inflammatory exudation in somatic cavities, accompanied by necrotic purulent or putrefactive foci in the organs, particularly where dispersion (metastases) or evidence of generalized infection or intoxication exists, such as congestion of lymph-glands, degeneration of organs, dirty-grey discoloration of musculature, punctiform haemorrhages (petechiae), viscous or mal-coagulated blood, etc.
	(*b*) infiltration of connective subcutaneous or intermuscular tissue, extensive, aqueous, sanguineous, or serous
	(*c*) presence of meat-poisoning bacteria
	Jaundice, resulting from an infectious disease, where the meat retains a strong yellow or yellowish-green discoloration for 24 hours after slaughter, or where the animal is emaciated
	Petechial fever
	Polyarthritis in calves and foals
	Rabies
	Repugnant appearance, strong urinary or sexual odour, fish-like odour or taste, disagreeable odour or taste due to fodder, medicines, disinfectants, or other such substances; any other abnormalities of odour, taste, colour, formation, or defence mechanism, noted in particular after the boiling or frying test
	Sarcosporidiosis, where the meat is aqueous and visibly discoloured
	Sores, purulent or gangrenous, generalized

Country	*Categories*
Switzerland (*continued*)	Tetanus, where the animal is not slaughtered shortly after onset of the disease Trichinosis in pigs and boars Tuberculosis : (*a*) acute miliary, generalized, or of recent infection through the blood-stream (*b*) chronic tuberculosis in many of the internal organs and several regions of the organism or the corresponding lymph-nodes (*c*) tuberculosis confined to the internal organs but accompanied by cachexia or a repugnant appearance in the meat Tumours, widespread in the musculature, lymph-nodes of the muscular system, skeleton, or in several internal organs Also designated as unfit for human consumption : meat of animals less than 8 days old, of animals killed by injury (lightning or accident, for example), where not immediately eviscerated or where inadequately bled, of sick animals slaughtered at the point of death, or of animals which have had to be destroyed *Note.* The fat of pigs coming under the above provisions relating to cysticercosis, trichinosis, and tuberculosis may be handed over to the owner for his personal use after being rendered down under official control, provided the owner is not a butcher, a restaurant-keeper, or a hotel-keeper.
Tunisia	In practice, the relevant French legislation is applied in all Tunisian slaughterhouses
Turkey	All septic infections and diseased or abnormal conditions which might render consumption of the meat harmful (including various types of pneumonia, septicaemia, pyaemia, etc.)
United Kingdom :	
England and Wales	Abnormal odour, associated with disease or other conditions prejudicial to health Actinobacillosis, generalized Actinomycosis, generalized Anaemia, advanced Anthrax Blackleg Bruising, extensive and severe *Cysticercus bovis*, generalized *Cysticercus cellulosae* *Cysticercus ovis*, generalized Decomposition, generalized Emaciation, pathological Fever, including salmonellosis Foot-and-mouth disease Glanders

Country	*Categories*
United Kingdom:	
England and Wales (*continued*)	Immaturity: (*a*) carcasses of stillborn or unborn animals (*b*) oedematous carcasses, and carcasses in poor physical condition
	Jaundice Malignant catarrhal fever Mastitis, acute septic Melanosis, generalized Metritis, acute septic Oedema, generalized Pericarditis, acute septic Peritonitis, acute, diffuse, septic Pneumonia, acute septic Pyaemia, including "joint-ill" Sarcocysts, generalized Septicaemia or toxaemia Swine erysipelas, acute Swine fever Tetanus Trichinosis Tuberculosis, generalized Tumours, malignant or multiple Uraemia
Scotland	Actinomycosis, generalized Anaemia, if pronounced Anthrax Blackleg Bruising, general, extensive, and severe, with or without gangrene *Cysticercus cellulosae* Decomposition Dropsy, general Emaciation, general pathological Fever Glanders Immaturity: carcasses of stillborn or unborn animals Jaundice Malignant catarrh Malignant neoplasms, unless localized in situation and effect to one organ Mastitis, acute and septic or gangrenous Melanosis, generalized, or any generalized pigmentation Metritis, acute septic Odour, associated with disease or otherwise prejudicial to health Pericarditis, septic Pneumonia, septic or gangrenous Pyaemia, including "joint-ill" Rickets, with malnutrition

Country	*Categories*
United Kingdom:	
Scotland (*continued*)	Sarcocysts, if generalized in the musculature and visible to the naked eye
	Septicaemia or septic intoxication
	Swine erysipelas
	Swine fever
	Tetanus
	Trichinosis
	Tumours, multiple, in musculature
	Uraemia
Yugoslavia	Anaemia
	Anthrax
	Anthrax, symptomatic (blackleg), and other emphysematous diseases
	Carcasses of:
	(*a*) animals slaughtered in emergency in accordance with the regulations in force, where not immediately eviscerated upon slaughter
	(*b*) animals dying from natural causes or slaughtered at the point of death
	(*c*) stillborn or unborn animals
	Cattle plague
	Dropsy, generalized, serious, where changes do not disappear within 24 hours at the latest
	Emaciation, extreme, caused by disease
	Encephalomyelitis, infectious, in the pig
	Glanders
	Influenza in young pigs
	Jaundice, where the carcass as a whole retains a strong yellow or yellowish-green discoloration for 24 hours after slaughter, or where a repugnant odour or taste is revealed by the boiling or frying test
	Pronounced urinary or sexual odour, strong fish-like or fish-oil odour, repulsive odour or taste due to the use of medicines, disinfectants, etc., noted 24 hours after slaughter upon application of the boiling or frying test
	Pseudo-rabies
	Putrefaction or other such forms of decomposition
	Rabies
	Septicaemia, haemorraghic, in cattle
	Septicaemia or suspected septicaemia, in certain conditions
	Swine erysipelas
	Swine plague
	Tetanus
	Tuberculosis
	Tumours or widespread oedemas in the muscles, lymph-nodes, or bones
	Any other disease causing important changes in the meat or fat

Judgement of Meat

The following are the terms usually applied in the various countries in the judgement of meat for human consumption:

Country	*Terms of judgement*
Austria	Approved Inferior Conditionally approved Total condemnation
Belgium	Unconditionally approved Conditionally approved Conditionally approved subject to sterilization or freezing Meat seized
Denmark	Unconditionally approved Conditionally approved Total condemnation
Finland	Approved Conditionally approved Total condemnation
France	Approved for consumption Seized for delivery to disposal plants
Germany	Approved Inferior Conditionally approved Total condemnation
Greece	Fit for consumption Fit for consumption under appropriate conditions Inferior Unfit for consumption
Ireland	Passed Rejected or condemned, complete, partial, or organs only
Italy	Approved for consumption Conditionally approved: (*a*) for sale as inferior meat (*b*) for sterilization and sale as inferior meat Partial seizure Total seizure
Morocco	Approved for sale as: (*a*) superior-grade meat (*b*) 1st grade meat (*c*) 2nd grade meat (*d*) 3rd grade meat

Country	*Terms of judgement*
Netherlands	Approved Conditionally approved for sale: (*a*) as inferior meat (*b*) subject to sterilization (*c*) subject to freezing for a 10-day period at −10°C (14°F) (*d*) subject to salting Total condemnation
Norway	Approved, class I Conditionally approved, class II Condemned
Portugal	Approved R = rejected O = further inspection F = freezing E = sterilization
Spain	Fit for consumption Seizure, total Seizure, partial
Sweden	Approved Conditionally approved Partial condemnation Total condemnation Approved as animal food Approved for technical use
Switzerland	Approved for consumption Conditionally approved for consumption Unfit for consumption
Tunisia	Approved Conditionally approved Condemned
Turkey	Approved for consumption Approved subject to sterilization Approved subject to freezing Condemnation
United Kingdom:	
England and Wales	Passed Condemned
Scotland	Passed Detained Seized Condemned
Yugoslavia	Fit for human food Unfit for human food Partially or conditionally usable

Slaughterhouses and Premises for Storage, Processing, and Sale of Meat

Legislation is in force in all the countries covered by the survey prescribing approval for all establishments intended for use or in use as slaughterhouses, and all premises where meat or meat products are stored, processed, and/or sold. France excludes cold-storage premises from this provision. In Finland, approval of the local Board of Health only is required for cold stores and butchers' shops. In Tunisia, the law applies to urban communal centres only.

The premises covered by this legislation are under constant public-health supervision and control in all these countries.

Handling and Transportation of Meat

With a few exceptions, the countries concerned have regulations in force governing the maintenance of cleanliness in the handling and transporting of meat, offal, and meat products. In Austria, these regulations are issued by each federal province. Belgium and Germany are both engaged in preparing regulations in the matter. Finland's provisions form part of its general public-health regulations. In France, the regulations in question are at the local level and a similar position obtains in Morocco. Portugal has no effective regulations ; control is occasionally exercised by municipalities. There are a number of municipal regulations governing transportation of animals and meat to slaughterhouses and butchers' premises in Tunisia.

Medical Examination of Food-Handling Staff

Slightly more than half the countries surveyed have regulations prescribing physical examination for communicable diseases of staff employed in the meat industry, both before and/or during employment.

In Austria, this matter is governed by the law concerning carriers of bacilli. Belgium, Denmark, France, Norway, Switzerland, Tunisia, and part of the United Kingdom (Scotland) have no regulations of this kind. In Finland, such regulations are included in the general public-health regulations. In Morocco, the regulations in force apply only to staff in meat-processing plants, and in Sweden to dairy personnel only.

MEAT-HYGIENE PROBLEMS IN TROPICAL AREAS

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Elsewhere in this monograph particular attention is given to meat-hygiene practices relative principally to conditions in economically advanced and industrialized communities. This paper will be devoted to problems in meat hygiene encountered in the rural and lesser developed areas of tropical and other warm-weather countries.

Geographical and other factors, such as local customs and type and degree of economic development, necessitate modifications of approach towards achieving a safe and wholesome meat product for human consumption. In economically developed countries with a temperate or cold climate it is not too difficult to implement effective procedures in meat hygiene, but major areas of the world do not fall into this category. The tropical areas in general are characterized by a climate difficult with respect to meat and its preservation, a lack of sufficient funds to invest in expensive mechanical equipment and buildings, a dearth of trained personnel, insufficient and irregular supplies of electricity and good water, and a population frequently uneducated in modern sanitary practices. These disadvantages have to be met, and it is hoped that a brief discussion of the problems faced, and indications of how they might be solved within present limits of available facilities, will contribute to economic and health advances without the inevitable delay, caused by preoccupation with other health priorities, in the long and gradual development now being undertaken in most of these areas.

The vicious cycle of poverty and poor sanitation, and their effect on meat-hygiene practices, cannot be broken by little improvements here and there for it is unfortunately true that the achievement of the level of meat hygiene reached in the more developed countries requires substantial capital investment in buildings and equipment, and an adequate core of trained personnel. Nevertheless, a start can be made in the less fortunate communities, and it is the purpose of this paper to bring to the fore the possibilities of improvement with a minimum of expense and trouble.

In the discussion to follow, space limitations necessitate only a general coverage of the principal problems. These can conveniently be grouped under the headings:

(*a*) the abattoir

(*b*) ante-mortem inspection and care of animals

(*c*) procedure for slaughter of animals and dressing of carcasses

(*d*) post-mortem inspection and the major zoonoses

(*e*) the marketing of meat

(*f*) health control of meat handlers

Before, however, considering these technical aspects of meat hygiene, two points require emphasis because they overshadow almost all the technical considerations to follow. The first is the factor of deep-rooted local customs and tastes. An accompanying and often competing consideration towards producing a wholesome and safe meat product is the fact that this product must be acceptable in appearance and taste to a local population group. Meat which might be considered unacceptable or even repulsive in one part of the world may be highly desired elsewhere. Thus, frequently we find in North and South America, Europe, and Africa, only very slightly heated or lightly processed meat being favoured, while in other countries only well-cooked meat is consumed. Conversely, sterilized meat is perfectly acceptable to certain population groups while elsewhere such meat cannot find a ready market.

The second factor to be kept in mind is that good meat hygiene cannot be legislated into existence. Where little or no economic basis exists for recommended procedures, the mere enactment of laws which would cause undue hardship to the local butcher, or high prices to the consumer, would soon be without effect and would be circumvented by such practices as adulteration and other outright evasions of the law. This only serves to retard any eventual improvement sought. Thus, in working towards a progressive betterment of meat hygiene, and food hygiene in general, gradual steps must be taken, the economics of the local situation being kept paramountly in mind, and the necessity for education of the public being given equal attention.

The economic and educational problems should be attacked in combination. It is usually not difficult to convince people of the enormous economic losses caused by live-stock diseases which are discernible in carcass meat, such as the numerous parasitic infestations and various septicaemias commonly found in warm-weather countries. Scientific arguments alone stressing such factors as the necessity for cleanliness and refrigeration will not go far unless the accompanying benefits, particularly

economic, are made clear. However, education in this connexion has succeeded even in the backward bush areas of Africa, where it was shown that the previous flush seasons of availability of meat succeeded by long periods of scarcity could be overcome when a more rational and scientific approach was substituted for the primitive but age-old methods.[4]

The Abattoir *

Abattoirs vary in size from the backyard of the local butcher to the great meat-producing establishments geared for export trade. The main features to be considered in discussing the abattoir are its site, size, design and equipment, and management arrangements.

Site

Of primary consideration in choosing the site are: the availability of pure water, accessibility to transport and electric power, and distance from population to be served. All these points must be weighed individually and collectively and their relative importance determined in any specific situation. It is useless for an abattoir, no matter how well-constructed, to be located far from the point of main distribution of its meat products unless transportation is quick and dependable. In this connexion a difficult choice often arises as to whether to locate an abattoir near the source of supply of live-stock, which would reduce the often considerable distances the animals must travel before slaughter, or to locate it near the community to be served. Frequently live-stock must travel on foot for several days to reach the abattoir, and this naturally results in appreciable losses in weight and unnecessary suffering, especially where water and feed points *en route* have not been arranged. In addition, live-stock which have travelled long distances on foot or in transport are frequently insufficiently rested before slaughter, with a resulting deterioration in the quality of the meat.

An adequate and clean water supply is an outstanding necessity, but this requirement is frequently the one most often lacking. Abattoirs are often conveniently located by rivers or by the sea (see Fig. 1), but pollution problems are troublesome both from the point of view of polluting a water supply with effluent from an abattoir, and from that of using an already polluted water supply for cleaning purposes in abattoir routine (see Fig. 2).

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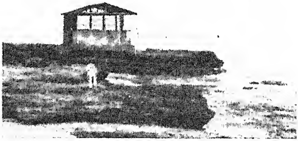
* For further detail on the design, equipment and management of the abattoir see articles by Benoit and Scaccia Scarafoni on pages 161 and 125 respectively.

Size

The size of the abattoir, of course, depends upon local needs, but in the rapidly expanding urban communities of today it is wise to provide for possible future enlargement of facilities. A reorganization in economy may require a considerable change of plans with respect to size. In many tropical areas there is now a shift from the individual small rural abattoirs to large centralized plants which would render obsolete the smaller establishments. The large reserves of meat and by-products often found in inaccessible areas can thus be utilized for export purposes (see Fig. 3).

FIG. 1. SIMPLE ABATTOIR BY THE SEA MANTA, ECUADOR



Kindly provided by Dr G. Mortensen, Virum, Denmark

FIG. 2. USE OF POLLUTED WATER OF DRAINAGE DITCH FOR WASHING VISCERA

Kindly provided by Dr G. Mortensen, Virum, Denmark

Design and equipment

The type of building may consist of the outdoor pavilion type which is popular in many warm-weather countries (see Fig. 4, 5), the wooden shack (see Fig. 6) or barrack type, the screened semi-open-air building (see Fig. 7), or the small concrete and stone building very suitable for rural areas (see Fig. 8). It is not uncommon in some areas of the Far East to see large abattoirs without any protective covering whatsoever and containing only stone floors and gutters and a few rudimentary racks to hang carcasses (see Fig. 9). The advantages and disadvantages of the various types illustrated can readily be seen from the standpoint of possibilities for applying sanitary methods.

Suitable corrals, preferably with shade, for resting animals before slaughter and for the carrying-out of ante-mortem examinations should be provided (see Fig. 10). Wherever possible, runways should be built to enable cattle to be driven to the abattoir quietly and without crowding; this will prevent undue excitement on the killing floor (see Fig. 11).

Internal equipment need not be elaborate unless large-scale factory operations are envisaged, in which case the most modern machinery is needed (see Fig. 12). The basic equipment consists of easily cleaned and movable hooks for hanging the carcasses, overhead rails for internal transport of the carcasses in large abattoirs, impervious tables or benches (preferably of metal or glazed tile) for handling viscera, and hand-carts for transporting viscera. An adequate supply of clean water and good lighting are essential. Such items as scalding-vats (see Fig. 13) and dehairing machines for hogs, etc., are required when these animals are handled.

Facilities for refrigeration require special mention. Their advantages require no elaboration but, at the present time, many of the tropical countries cannot afford elaborate installations, particularly in small abattoirs.

FIG. 3. LARGE MODERN ABATTOIR SERVING LOCAL AND EXPORT NEEDS: ATHI, KENYA

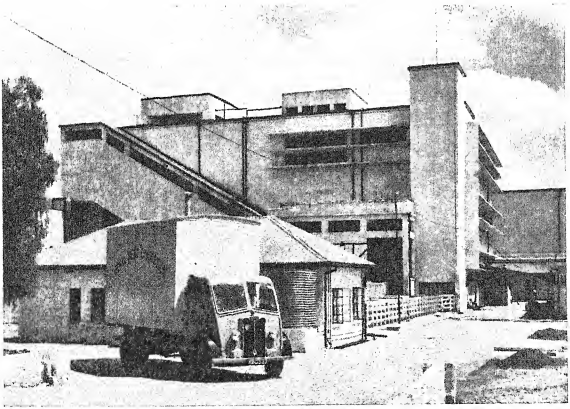


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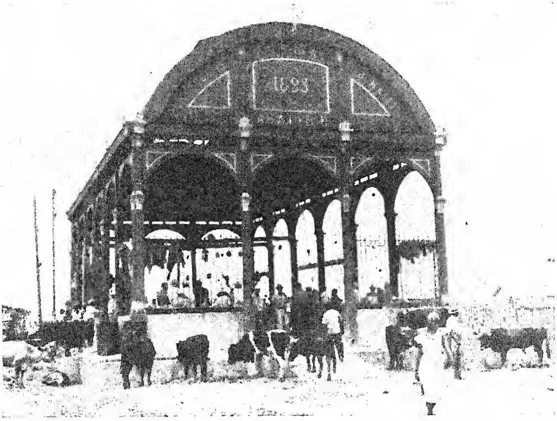
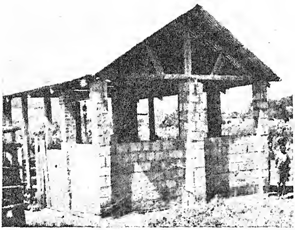
FIG. 4. PAVILION-TYPE ABATTOIR: HAITI



Kindly provided by Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

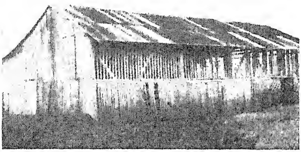
The common pattern of quick disposal by sale of meat from freshly slaughtered animals, encountered in many tropical areas, does not necessitate such large installations, but small limited facilities are particularly useful for the special treatment of meat carcasses containing certain parasites, for example, cysticerci, to render them safe for human consumption. This also holds true for meat sterilization equipment. It is well to stress, however, that a premature provision for large-scale refrigeration in an abattoir may even be disadvantageous unless continued refrigeration is available for the meat until it reaches the consumer, because

FIG. 5. MODIFIED PAVILION-TYPE ABATTOIR: KENYA



Kindly provided by Dr A. Ginsberg, Department of Veterinary Services, Kenya

FIG. 6. WOODEN SHACK-TYPE ABATTOIR : PARAISO, COSTA RICA



Kindly provided by Dr G. Mortensen, Virum, Denmark

once meat is refrigerated it is subject to rapid decomposition, especially in hot climates, after it leaves the refrigerator.

For the slaughter and dressing of poultry a separate building should be provided, or the quarters should be quite distinct and isolated from other installations of the abattoir dealing with the larger animals.

The main principle in designing small abattoirs is to provide for the separation of "clean" and "unclean" operations with different exits for the final products. Slaughtering- and bleeding-pens should be separated as far as possible from the dressing of the carcass itself. In the dressing procedures it is further advisable to separate the handling of the hides, skins, stomachs, intestines and feet from the edible portions such as the meat and organs. Every attempt should be made to keep carcasses off the floor during dressing procedures, and mechanical hoists and overhead rails are used for this purpose (see Fig. 14). Where such equipment is not feasible, simple movable hooks should be provided. The floors and walls of the abattoir should be made of impervious materials which can be easily cleaned.

Provision should be made for the sterilization or other type of disposal of condemned carcasses. The most

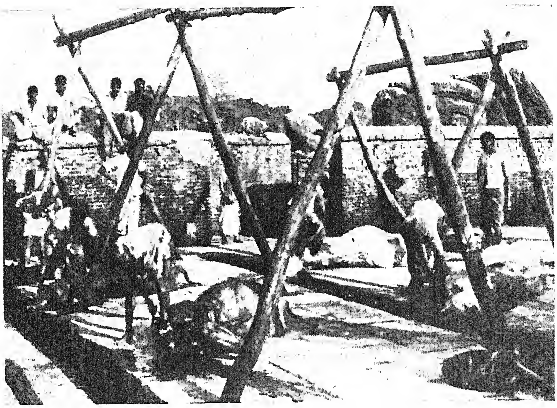
FIG. 7. SCREENED SEMI-OPEN-AIR ABATTOIR : TELA, HONDURAS

Kindly provided by Dr G. Mortensen, Virum, Denmark

FIG. 8. NEW CONCRETE RURAL ABATTOIR: COSTA RICA

Kindly provided by Dr G. Mortensen, Virum, Denmark

FIG. 9. OPEN-AIR ABATTOIR: INDIA



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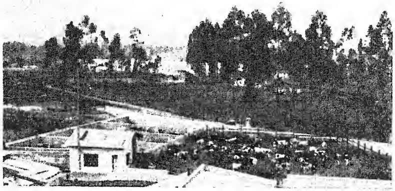
satisfactory method is heat sterilization, with salvage of the by-products for fertilizer or feed purposes. Present practices in many tropical countries are unsatisfactory in this connexion, and such diseases as anthrax and hydatidosis are perpetuated and spread through lack of attention to this detail (see Fig. 15).

FIG. 10. ABATTOIR CORRALS: QUITO, ECUADOR



Note general holding corral and separate corrals for animals removed as a result of ante-mortem examination.

Kindly provided by Dr G. Mortensen, Virum, Denmark

FIG. 11. CATTLE RUNWAY LEADING TO ABATTOIR: TELA, HONDURAS

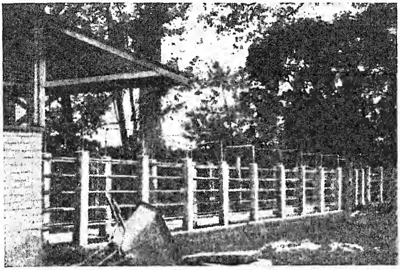


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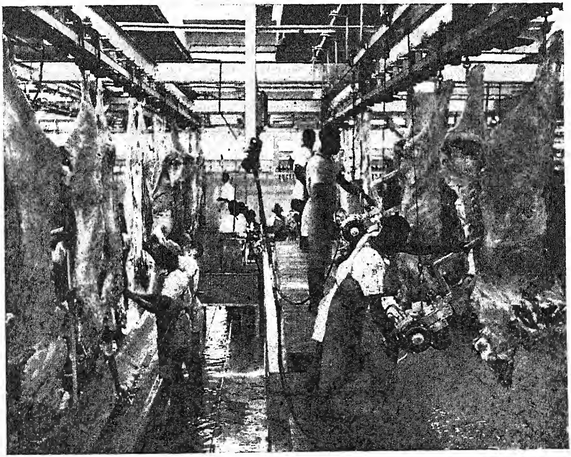
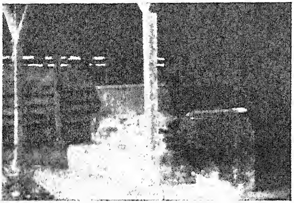
FIG. 12. DRESSING-FLOOR OF MEAT PLANT: KENYA



The plant is that shown in Fig. 3; note use of modern machinery.

Kindly provided by Dr A. Ginsberg, Department of Veterinary Services, Kenya

FIG. 13. SIMPLE SELF-CONTAINED SCALDING-VAT FOR HOGS



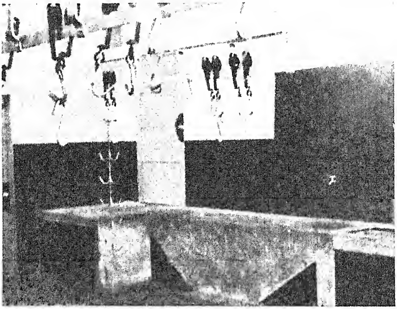
Its disadvantages are lack of facilities for drainage and for frequent change of water, and its position outside the abattoir proper.

Kindly provided by Dr G. Mortensen, Virum, Denmark

Management

In general two systems are widely practised. In the first, the abattoir operations are under the direction of a single authority, governmental or private, employing a permanent staff of workers. This system is more practicable for large abattoirs, and sanitary improvements and arrangements can usually be introduced. The second system is the use of space in the abattoir by local individual butchers who carry out all their own operations. With this system it is practically impossible to separate "clean" from "unclean" operations, and usually the operations are carried out with much confusion and with the attendance of unauthorized persons. This creates a serious lack of discipline and works against any possibility

FIG. 14. SINGLE OVERHEAD RAILS AND MOVABLE HOOKS FOR TRANSPORTING CARCASSES IN ABATTOIR

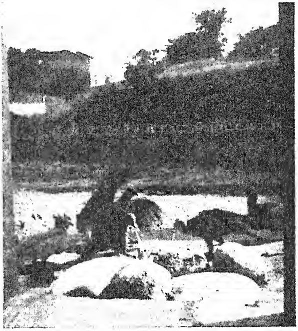


The recesses shown under the concrete tables, and the tables themselves for handling viscera, are difficult to keep clean.

Kindly provided by Dr G. Mortensen, Virum, Denmark

of hygienic procedures (see Fig. 16). Various combinations of the two systems are used, often with considerable success, for overcoming the disadvantages of the second.

FIG. 15. VULTURES ATTACKING FRESHLY DISCARDED CONDEMNED VISCERA AND CARCASSES

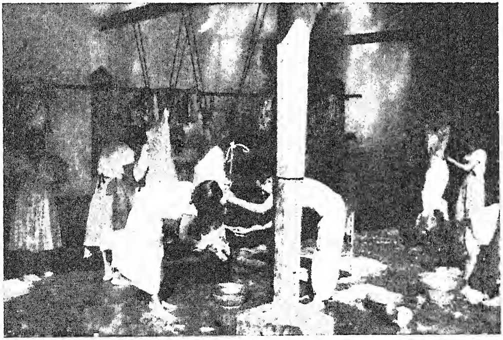


Kindly provided by Dr G. Mortensen, Virum, Denmark

Ante-mortem Inspection and Care of Animals

These procedures are too frequently omitted, primarily because their value is unrecognized ; corrals and resting pens are necessary if they are to be carried out properly (see Fig. 10, page 348). Veterinarians and trained lay inspectors usually have no difficulty in picking out clinically ill animals whose meat would provide a source of danger for both

FIG. 16. OPERATIONS IN ABATTOIR CARRIED OUT BY INDIVIDUAL BUTCHERS



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humans and animals. This is particularly important in areas where foot and mouth disease, anthrax, rinderpest and other epizootic diseases are serious problems. The stringent application of ante-mortem inspection and veterinary control can do much to assist in the control of these diseases by noting areas where infected animals originated. When animals have been transported for long distances, ante-mortem inspection ensures that they are properly rested before slaughter—a humane practice and one which results in better meat.

One of the procedures commonly used in the Latin American countries in ante-mortem inspection is palpation of the tongue of hogs for cysticerci cysts (see article by Schmid, Fig. 8, page 227). This is usually performed by a prospective buyer of hogs at an abattoir, less often by a veterinary or lay inspector. In the latter instance, affected hogs are marked and the meat of such carcasses is usually used to prepare " fritada ", which are cheap and are considered something of a delicacy by the poorer population groups. " Fritada " are prepared by cutting the meat into thin strips and frying them in a separate part of the abattoir. When properly performed, this kills the cysticerci cysts and salvages meat which would otherwise be unavailable for human consumption.

Slaughter and Dressing *

Methods of slaughter **

Methods vary widely in different areas of the world, and include simple decapitation in parts of India, pithing (severing the medulla) in the Mediterranean and some Latin American countries, severing of the major blood-vessels without previous stunning, and stunning by a blow or gun before slaughter. Electrical stunning before slaughter is gradually making headway in many areas, and this procedure should be encouraged wherever possible. The refined method of CO_2 stunning of hogs (see page 490) is not applicable in the smaller abattoirs.

Unfortunately the adequate collection of blood from slaughtered animals and the processing of this valuable by-product is not performed in many of the tropical areas. It is not a difficult procedure if a raised gutter which can easily be kept clean is provided in the killing-pen. If the blood is to be used as fertilizer or animal feed, formaldehyde can be added as a preservative until the liquid blood can be processed, especially when it has to be transported for processing to a point distant from the abattoir.

* The reader is referred to an excellent review article entitled " Microbiological implications in the handling, slaughtering, and dressing of meat animals ", by John C. Ayres, published in *Advances in food research*, vol. 6, New York, 1955. The author reviews the major factors contributing to the microbiological flora of meat as they affect hygienic and keeping qualities. Detailed consideration is given to such aspects as ante-mortem fatigue, slaughtering and dressing procedures, and storage.

** See also articles by Blom and Croft on pages 137 and 147 respectively.

Dressing of carcasses

The essential fault to be found in this procedure in many warm-weather countries is the failure to provide for hoists or hooks which permit the dressing of carcasses to take place off the floor (see Fig. 9, page 348). The contamination resulting from floor-dressing of carcasses is, of course, considerable, especially where removal of the hides and cleaning of the stomachs are carried out in the same compartment as the dressing. The lack of an adequate water supply is most seriously felt at this point.

The nature of dressing and cuts of carcasses is influenced by local customs, which vary from a preference for whole sides to that for small pieces of meat. In tropical countries the latter preference has a distinct advantage, especially where no refrigeration facilities are available, in that cooling takes place much more quickly, although under unsanitary conditions it also assures that contamination is widespread in the meat. In most tropical areas where meat is sold within a few hours after slaughter it is usually well cooked. The frequency in these areas of gastro-intestinal disturbances attributable to meat, however, attests to the inadequacy of the safeguards used at present.

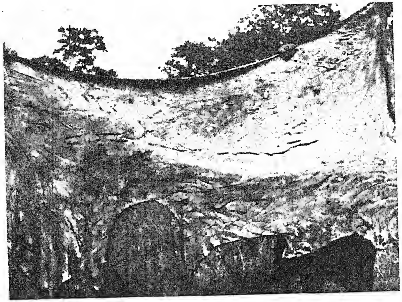
Inflation of carcasses by air is commonly practised, especially in eastern Mediterranean and south-east Asian countries. This consists of inserting a needle connected to a tube supplying compressed air under the skin of the hide and forcing air throughout the carcass. Removal of the hide is facilitated and the resultant emphysema of the subcutaneous tissue gives the surface of the carcass an appearance attractive to the local consumers. It has been discovered, however, that the air finds its way to deeper parts of the carcass and thus contamination introduced with the air is dispersed widely throughout the meat. Where compressed air is not available—and this is not infrequent—the air is forced through by mouth, which adds further to the hazards of contamination. Lungs are also sometimes inflated in a similar manner, and the trachea tied off to keep the air trapped as far as possible.*

After the dressing of the carcasses a thorough washing-down with clean water is desirable to remove as much of the surface contamination as possible; frequently, however, water is not available for this purpose, or polluted water is used.

Hides and intestinal casings are usually a valuable by-product even in small abattoirs. Removal of hides is usually done by hand, and unless the worker is very skilful the value of the hide may be lessened considerably by cuts (see Fig. 17, 18).

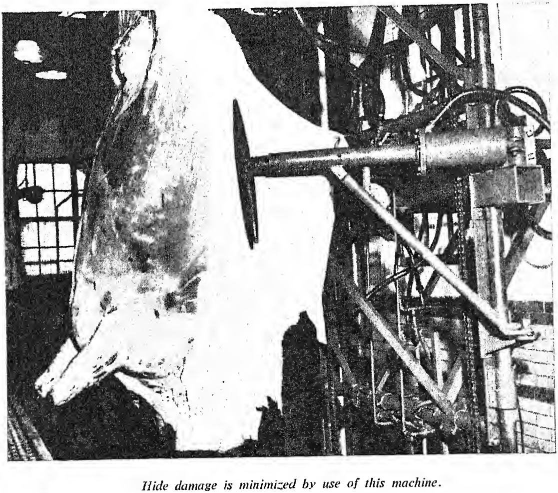
* Another undesirable procedure in some countries is the custom of leaving the rectum *in situ* in dressed sheep and goats, to demonstrate to the purchaser the fatty covering on the rectum as an indication of the well-nourished condition of the carcass. Faecal contamination is almost inevitable.

FIG. 17. HIDE LESSENED IN VALUE BY CUTS MADE DURING UNSKILLED REMOVAL



Kindly provided by Dr G. Mortensen, Virum, Denmark

FIG. 18. HIDE PULLER



Hide damage is minimized by use of this machine.

Kindly provided by Canada Packers Ltd, Winnipeg, Canada

Post-mortem Inspection and the Major Zoonoses

While it is true that all countries try to salvage as much meat as possible for human consumption, this aim becomes an overriding consideration in the lesser developed areas. In wealthy countries, where any doubt whatsoever exists concerning the safety of the meat product the usual judgement of meat inspectors is in favour of rejecting the suspected meat, of holding it aside pending the outcome of bacteriological examinations, or of sterilizing the product before permitting it to leave the abattoir. Such severe judgements extend to carcasses showing signs, such as emaciation, which are indicative of poor quality but which *per se* do not necessarily mean that the meat is dangerous from the standpoint of human consumption. These precautions are certainly justifiable and are to be recommended for the more wealthy countries, but if they were to be followed stringently in the lesser developed areas the population would be deprived of very large amounts of scarce and valuable meat protein, owing to the high level of parasitic infections and other abnormalities found in the carcasses of slaughtered animals in tropical and warm-weather areas. Consequently, alternatives are sought to the rigid inspection judgements practised in many of the western European and North American countries. Furthermore, facilities for bacteriological examination and refrigeration for use in holding suspected carcasses and for treating certain parasitisms (such as cysticercosis and trichinosis) are usually lacking in the tropical areas, and judgements must be made and procedures followed in the face of these deficiencies.

Another difficulty, more remediable than the ones previously mentioned, is the failure to provide for the suitable identification of viscera from a carcass, so that frequently the viscera belonging to one carcass is examined haphazardly and without relation to the carcass meat; or, because of local customs, the thoracic organs of the small ruminants are left *in situ* where they cannot be adequately inspected. It need not be stressed that every effort should be made to identify properly the viscera belonging to a carcass, and to remove and inspect the thoracic organs along with the rest of the meat (see Fig. 19).

In most of the lesser developed areas there are insufficient adequately trained personnel for meat inspection, particularly veterinarians. However, the over-all responsibility of meat inspection in the larger abattoirs is usually under the supervision of a veterinarian who is called upon to make a final judgement on a carcass where some doubts arise in the minds of lay inspectors. The pressure of time and the quantity of material during rush periods are so great that for the most part little more than a perfunctory examination by the veterinarian can take place. The training

FIG. 19. "BELT-LINE" SYSTEM OF VISCERA INSPECTION

Viscera in tray are from carcass suspended behind inspector ; both trays and carcasses are in continual movement.

Kindly provided by the Agricultural Research Service, US Department of Agriculture, Washington, USA

of lay inspectors * therefore assumes particular importance and in many tropical countries these officials are used to great advantage. The lay inspectors can do much to assure that organs and viscera of carcasses are properly identified, and their training should be such as to include the cutting and examination of the major regional lymph-glands as well as the gross examination of the organs.

A difficulty frequently faced in abattoirs is the attempt of inspectors to carry out their duties amidst the confusions of the slaughter and dressing of the animals. However, an inspector should witness the actual slaughter and dressing of the carcass. If some abnormality is detected, the carcass and organs should be removed to a convenient place for a more leisurely and detailed examination.

The main difficulties encountered by meat inspectors in their judgement of carcasses are the parasitic diseases very common in warm-weather countries, septicaemias, and certain chronic affections such as pleuropneumonia and nutritional disturbances. It is very difficult to advise rule-of-thumb procedures for these various conditions under the circumstances found in these areas. Common sense has to play a large part in decisions to be made. Thus parasitic infestations such as flukes and the helminthic

* See article by Thornton, page 301.

diseases, at least those which are not dangerous to human health, can be handled by dissecting away the most grossly affected parts, but they should not be ignored entirely as is too often done. (A useful guide concerning post-mortem judgements under tropical conditions can be found in Annex 15 (see page 471) which deals with the problems as they have been met in Kenya.) Problems concerning the major zoonoses are considered below.

Anthrax

This disease is quite commonly encountered in abattoirs of tropical countries and raises very serious questions concerning the handling, judgement and disposal of carcasses. Anthrax can often be detected if proper ante-mortem inspection has been carried out, but the disease can be overlooked, and it is not uncommon to find suspected anthrax in a carcass on the abattoir floor. Even to an experienced inspector the clear differentiation of anthrax from other septicaemias is not always easy, and where bacteriological facilities are not available the use of the Ascoli test is very helpful (see Annex 14, page 447). This test can be performed even under rudimentary conditions, and its use is advised in those places where anthrax is a troublesome problem. Care should be taken to remove the suspected carcass from the abattoir floor and to avoid further contamination of the environment. Terminal disinfection of the abattoir should be carried out with 2% lye solution.

Carcasses infected with anthrax should, of course, be destroyed completely, preferably by incineration. Burial in the ground, unless accompanied by suitable use of strong disinfectants (lime), leaves the danger of subsequent digging-up by predatory animals, and spread of the disease.

Cysticercosis

This condition is particularly troublesome in many areas of the tropics and warm-weather countries, and certain aspects of the problem deserve detailed discussion.

The present procedure of masseter and cardiac muscle cuts were found to be deficient in a careful study carried out on 15 completely dissected carcasses from animals originating in Tanganyika.[6] It was found that the most practicable and informative site for muscle incisions involved those of the neck and hump (for zebu-type cattle). The study indicates that the best site for the cuts would be on the medial side of the thigh and leg, but this would be difficult during meat inspection routines. The authors also make the interesting observation that even stone-like cysts, which would ordinarily be passed by an inspector as dead, can and do evaginate under certain conditions.

Ginsberg [3] recently reported on his findings and extensive experience with the cysticercosis problem. In 14 operational days at an abattoir near Nairobi, Kenya, he examined 1648 adult cattle of which 358 (21.7%) were found to be infected with *Cysticercus bovis*. He found the shoulder muscles, followed by the masseters, to be the sites of predilection; * out of the 358 infected cattle 102 showed cysts in the shoulder muscles only, 51 in the masseter muscles, 26 in the heart, and only 1 each in the diaphragm and flank. The remaining 177 cattle had cysts in two or more places, but in the majority of cases in the shoulder muscles as well. For routine inspection in areas where a high level of infection is combined with low sanitary standards, Ginsberg favours deep and long cuts in the shoulder and masseter muscles; where possible, as an added safety measure, other cuts can be added (cardiac, trunk, root of tongue). As Ginsberg points out, a mutilated carcass loses some market value and is subject to easier decomposition through contamination and flies, but these disadvantages are overweighed by the greater margin of human safety provided. Other significant findings reported by Ginsberg were as follows:

(1) 56.5% of young calves were found to be infested, which conflicts with present recommendations by some meat hygiene authorities that examination for cysticerci may be omitted in calves under 6 weeks of age.

(2) Viable cysts were found alongside of dead cysts (also reported by Jepsen & Roth [5] and Mann & Mann [6]); thus the passing of carcasses affected with one degenerated cyst, without freezing, was considered contrary to public-health interests.

(3) He compares his findings of 56.5% infection in young calves with that of 21% in adult cattle (248 of the infected animals were 5 years of age or older), but feels that the lower percentage in adult cattle resulted from a transfer to clean pasture rather than from the development of immunity. This finding of a high incidence in older cattle would conflict with the suggestion made that human infection might perhaps be controlled by limiting slaughter to adult animals.[8]

(4) Most of the infected carcasses (233 out of 358) showed less than 6 cysts; 125 showed 7 or more cysts. Ginsberg was unable, despite a "carcass mince examination", to substantiate the finding [6] that one observed cyst may indicate 167 or more hidden cysts under East African conditions.

Some of these more recent findings are of great interest when compared with earlier work, although such comparisons must be interpreted with caution because of the variables involved—for example, experimental

* As a result of further work on a total of 42 500 cattle of European origin and 12 850 o African origin, Ginsberg et al.[4a] concluded that the sights of predilection of *Cysticercus* cysts are as follows: shoulder muscles, tongue, heart, masseter and adductor muscles, oesophagus, and diaphragm.

versus natural exposure (uncontrolled dosage), different breeds of livestock involved, environmental conditions, etc. In European and North American cattle it has generally been agreed that the heart and masseter muscles are the sites of predilection for the bovine cysticerci cysts. This has also been observed by Australian [9] and Danish [6] workers, and both these reports add the tongue and diaphragm as favoured sites although they are less so than the heart and masseter muscles. It would therefore be advisable for each area to undertake its own study in this connexion to determine the sites of predilection for cysts under individual conditions, so that suitable inspection procedures can be followed.

The ratio of " observed " to " hidden " cysts is of some importance where lightly infested carcasses (6 or less " observed " cysts) are passed for human consumption after suitable processing. Ratios (observed/hidden) of from 1 : 1 for lightly infested carcasses, up to 1 : 20 [2] (and even 1 : 175 [6]) for heavily infested carcasses have been advanced. However, even though very careful processing would safeguard the human health aspect, from the standpoint of meat quality and consumer demand the distribution of grossly apparent " measly " beef cannot be recommended. Adequate processing would be the pickling, freezing or heat sterilization of carcasses as outlined in Annex 13, page 444, but these procedures should be used only in lightly infested carcasses.

The control of cysticercosis in cattle is made difficult by the low sanitation standards found in many tropical areas which result in contamination of pastures with human faecal matter. Human sewage is deliberately used as fertilizer, however, in some economically advanced countries and poses a problem to them also. The eggs of *Taenia saginata* can survive on pastures under various environmental conditions for several months [5, 9] and any ultimately successful control within the limits of practicability would appear to lie in proper pasture management, that is, " resting " infected pastures and preventing recontamination with human faecal matter. Here public education plus adequate treatment of sewage would not seem to be insuperable obstacles.* Adequate meat inspection proce-

* Silverman & Griffiths,[10] recently wrote an excellent review of the problems associated with sewage treatment for the destruction of taenia eggs. The authors found that most of the usual sewage treatment procedures, including rapid sand filtration, were ineffective in removing these eggs. Experimentally, " micro-straining " (using stainless-steel wire gauze) was capable of filtering out 90%-95% of the original concentration of eggs in solution. The role of birds appeared to be highly suggestive in the dissemination of taenia eggs. The authors concluded, on the basis of circumstantial evidence, that the apparent increase in bovine cysticercosis in Great Britain may be associated with a breakdown of formerly reliable sewage-treatment systems, attributable to : (i) the post-war increase in urban populations and therefore in the amount of water used per person, which thus overloads the treatment works; and (ii) the increasing use, in industry and homes, of surface-active and bactericidal agents such as detergents) which have considerably interfered with the processes of sedimentation, putrefaction, and oxidation. The authors point out that this combination of circumstances may result in an increased survival and dispersal of the tapeworm eggs excreted by even a small number of infected persons.

dures, and case finding and treatment of human infections, are necessary and desirable, but if used alone they do not strike at the heart of the matter—namely, prevention of infection in cattle.

Although less exact information is available with respect to cysticercosis in swine, the same general considerations apply as those given for bovine cysticercosis.

Trichinosis

The advantages and disadvantages of trichinoscopical examinations have been dealt with elsewhere in this monograph* and by the Joint FAO/WHO Expert Committee on Meat Hygiene.[11] The expense and lack of accuracy of this procedure weigh against the routine use of the trichinoscope in tropical countries where the incidence of trichinosis appears to be quite low.

Hydatidosis

The importance of this disease lies in both its human health and economic aspects. The dog is the most significant link in the biological cycle and for this reason efforts at control must be directed at this animal. The attack is made by mass treatment of dogs in enzootic areas with a suitable anthelmintic, proper disposal of the infected faeces,[12] and prevention of infection of these animals. The abattoir is the crucial focus and source of infection through improper disposal of affected viscera of slaughtered animals (see Fig. 15, page 351). The hydatidosis problem is faced in most abattoirs, but the heaviest level of infection is found in the tropical and warm-weather areas. This is because of the laxity usually encountered in disposal of infected viscera, and if the problem is to be met with any degree of success facilities for sterilization or other adequate disposal of infected meat must be provided. The preparation of simple sterilizers, or deep burial with lime of infected meat, are not difficult procedures, but in addition there is the necessity for keeping stray dogs out of abattoirs, and for intensive public education which should reach the general population, including the individual butchers. These methods have succeeded in certain highly enzootic areas of Latin America and the Mediterranean, so they should be equally applicable under similar disadvantageous conditions elsewhere.

From the epizootiological point of view, hydatid cysts in sheep and swine are the most dangerous as far as potential infection of dogs are concerned, because cysts in these animals are much more fertile than those found in cattle. Thus the most intensive efforts should be directed towards adequate disposal of infected viscera from sheep and swine,

* See articles by Dolman, page 45, Schmid, page 228, and Hood & Johansen, page 324; also Annex 16, page 495.

although cattle should not be overlooked in any comprehensive control programme.

Bovine tuberculosis

Fortunately, with few exceptions, a fairly low level of prevalence of this disease is found in the tropical countries, and the problem of salvage of meat is therefore not as acute as, for example, in European countries.* Nevertheless, and perhaps because of this lower prevalence, there tends to be a certain laxity in the judgement of carcasses showing even generalized infection, and this fault should be guarded against. (It is perhaps worth mentioning a recent finding where, by guinea-pig inoculation, tubercle bacilli were isolated not only from the musculature of animals showing acute generalized tuberculosis on post-mortem (62.8% positives obtained), but also from the meat of animals showing only small isolated lesions in one organ (10.8% positives).[7])

Salmonellosis

The level of salmonella infection and carriers in domestic live-stock in tropical areas has not been investigated to any appreciable extent. In these areas, however, human gastro-intestinal infections caused by salmonellae are common, and meat-borne infections are no doubt frequent, from contamination of meat both by human carriers and by contact with meat derived from infected cattle. Contamination from infected animals during the abattoir routine is an appreciable problem,[1] and only careful ante-mortem and post-mortem inspection combined with good abattoir hygiene can reduce the danger of widespread contamination.

Other diseases

In enzootic areas of infection, the importance of other diseases such as rinderpest, contagious pleuropneumonia, and foot and mouth disease lies in the contribution that an abattoir can make to their control, rather than in direct protection to human health which may be involved. As mentioned previously, a careful watch for these diseases and their proper reporting to the authorities concerned can do much to improve the effectiveness of control procedures through quarantine, vaccination, etc.

Trypanosomiasis, babesiasis, theileriasis and other tropical diseases are often encountered in slaughtered animals. These diseases are not dangerous as regards human transmission, but pose questions of judgement for the meat inspector in the form of carcasses showing some emaciation, as well as minor lesions (see Annex 15, page 471). The meat is of inferior

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* See article by Albertsen, page 263.

quality but is usually retained for human consumption because of the economic loss which would be involved.

Emergency and other slaughter. Specific diseases, as well as certain rural customs and practices found in lesser developed areas, often result in emergency or even regular slaughter of animals outside the abattoir, the carcasses being brought for inspection to the abattoir itself. This practice should be discouraged wherever possible, especially when the organs of the animal itself do not accompany the carcass.

The stamp. The abuse of the stamp of approval for carcasses should be guarded against. A too rigid withholding of the stamp by meat inspection authorities will encourage the use of fraudulent stamps but, at the same time, a too lenient use of this mark of approval will lead to a loss of confidence on the part of the public one is trying to educate to the value of meat inspection procedures.

Marketing

Meat

Once the meat leaves the abattoir it is essential that all the precautions taken up to this point be not nullified by subsequent poor handling of the meat itself. In warm-weather areas where refrigeration is lacking, meat must be disposed of to the consumer as rapidly as possible. As mentioned previously, this is a fortunate necessity since it decreases the opportunity for extensive bacterial multiplication. Innumerable faults in the handling of meat encountered in warm-weather countries could be mentioned, but these are largely caused by lack of facilities. However, even without modern equipment much can be done to correct many of these faults. For example, the transport of meat in trucks, carts and other vehicles can be improved if some attention is given to the rudiments of cleanliness and protection from flies.* Shops can usually be policed officially to ensure at least minimum consideration for protection against excessive exposure to contamination. Again, one must keep in mind the economic hardships which might be imposed on individual retailers, should legislation far beyond their capability to fulfil be enacted. A gradual progression of steps, and education of the public, accomplish much more than the best laws. Thus, at the beginning, the simple requirements that meat be not left exposed to human handling, animals, flies and dirt, and be kept cool or refrigerated wherever possible, could do much good until good meat retail practices are developed (see Fig. 20).

* A good practice is to provide for transport of the meat from the abattoir to the retailer in properly equipped municipal vans. A small charge for delivery is usually made to the retailer.

FIG. 20. SMALL BUT SANITARY MEAT STALL IN PUBLIC MARKET: CARTAGO, COSTA RICA

Note partitions to prevent handling of meat by customers and to keep out animals.

Kindly provided by Dr G. Mortensen, Virum, Denmark

FIG. 21. DRYING MEAT FOR PRESERVATION: KENYA

Reproduced by courtesy of the Kenya Information Office 836/11, and kindly provided by Dr I. Mann, Department of Veterinary Services, Kenya

By-products *

Through long experience many countries have developed their own approach towards preservation of meat under local conditions (see Fig. 21) and the preparation of various by-products. Many tropical countries depend on exports of intestinal casings, hides, bristles and other products for a large part of their income, and improvements in abattoir procedures could do much to increase these sources of income. In addition, the exploitation of such by-products as blood, intestinal contents and sterilized offal for animal feeds, fertilizer, gelatin, etc., could make an appreciable contribution towards offsetting operating expenses of the abattoirs.

Health Control of Meat Handlers

This is a thorny problem which has not, as yet, been solved too satisfactorily even in economically advanced countries. There, the tendency is away from regular bacteriological examinations of meat handlers, since such examinations may give a false sense of security because of the limitations of the diagnostic methods available, and the fact that infection can occur soon after an examination, with possible shedding of pathogenic organisms over a considerable period of time before the condition is detected. Much more effective is education of meat handlers in simple procedures of personal cleanliness, such as periodic washing of hands, use of nail-brushes, and frequent changes of protective clothing.[11] Every effort should be made to impel meat handlers to report immediately any illnesses involving diarrhoea, vomiting, sores, or discharging ears or wounds. Particular attention to these precautions should be given to food handlers in vulnerable positions such as hospitals, schools, and meat factories where meat products to be consumed raw are prepared. In these instances periodic bacteriological examinations of stools and urine, and blood serological tests (for typhoid), are valuable and should be applied.

Discussion

An attempt has been made to touch on the principal problems in meat hygiene referable to tropical and warm-weather countries. From a public-health point of view, the most elaborate hygienic precautions in the abattoir can largely be nullified by subsequent poor handling of the meat. It is therefore incumbent upon public-health authorities to focus their attack

* See article by Albertsen, page 263.

where it will be most effective, and this will vary according to local conditions. Public-health funds are too limited to waste on expensively constructed abattoirs combined with fundamentally faulty hygienic and inspection procedures ; or on abattoir, market or restaurant control regulations with large technical loopholes which serve to create either a false sense of security or a lack of meat products because of unnecessary condemnations. Equally, little or no control anywhere along the line usually means human disease, uncontrolled animal epizootics, the supply of highly contaminated meat to the consumer, and enormous wastage because of the poor keeping qualities of such meat. Education in food hygiene should start in the schools to help create a public which would not countenance unhygienically produced and sold meat. A very valuable procedure is the encouragement of sanitary methods by fostering healthy competition among food producing and retailing establishments through the award of a " certificate of merit ".

Progress in meat hygiene in tropical areas rests largely on parallel economic development and health education of the public. Such progress is not inevitable ; concrete measures have to be taken and steadily applied, with the precaution that the goal set should not be out of view of the immediate practicalities of any local situation.

ACKNOWLEDGEMENTS

In the preparation of this article, apart from my own experience, I have drawn appreciably on the work of WHO and FAO meat hygiene consultants to various tropical countries. In this connexion I should like to acknowledge my indebtedness particularly to Professor A. Jepsen, Royal Veterinary and Agricultural College, Copenhagen, Denmark ; Dr G. Mortensen, Virumvej 139-B, Virum, Denmark ; and Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England. Mr N. Reid of FAO, Rome, also gave many useful suggestions.

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ANNEXES *

* Annexes 6, 7, 8, 9, 13, and 14 (B) have been reproduced, with slight modifications, from the first report of the Joint FAO/WHO Expert Committee on Meat Hygiene, published as *World Health Organization : Technical Report Series*, No. 99.

ANNEX 2

NETHERLANDS REGULATIONS FOR ROAD TRANSPORT OF SLAUGHTER ANIMALS

General

Motor vehicles and trailers must comply with requirements concerning over-all dimensions, so that cattle, when loaded, will nowhere overhang the vehicle.

Tyres

Vehicles must be fitted with pneumatic tyres.

Loading-space

Flooring must be solid, even, and non-slip. Woods that may be used are oak, deal (not less than 5 cm thick), or oregon pine (not less than 3 cm thick).

For transport of small cattle and pigs, these thicknesses may be reduced by one-third and one-half respectively.

In a vehicle fitted for the transport of large cattle, wherever the flooring is laid lengthwise, supporting cross-beams must be placed at 50-cm intervals.

Where there are two decks for the transport of small cattle, the distance between must be not less than 90 cm. Where there are two or more decks for the transport of pigs, there must be a distance of not less than 50 cm between each. The flooring must be free of projections. Unavoidable sharp angles or projections in the flooring forming part of the vehicle must be rounded off, if necessary, by filling in with wood. For the transport of large animals, there must be a strong, removable cross-beam at a height of 100 cm above the floor for locking the ramp.

External walls

The floor-space must be surrounded by wooden sides, free of metal covering. Ventilation openings must not exceed 8 cm by 12 cm.

Where there is a door in one side, it must close properly and be fitted with a strong lock. The lower edge of the door must be not less than 2 cm and not more than 5 cm above the flooring.

Roof

The roof must either be fixed or consist of a well-fitting watertight canvas.

Loading ramps

Except for the transport of new-born calves, the vehicles must be provided with one or more loading ramps. These must have wooden cross-bars set at intervals of approximately 25 cm. Cross-bars must either be attached to the ramp by bolts with rounded heads counter-sunk in the wood or be laid between the boards of the ramp. The sides of the ramp must have no sharp projections. The length must be such that the inclination is not more than 30°. With the ramp down, the distance from the ground to the ramp must not exceed 12 cm. Any gap between the ramp, when down, and the floor space must not exceed 2 cm. Where it is less than 100 cm in width, the ramp must be provided with removable hand-rails at each side, the height being not less than 75 cm. The ramp must so lock as to preclude accidental opening.

Means of attachment

For fastening cattle, two methods may be used:

(1) by rings or clamps with a rounded finish attached to the walls;

(2) by a horizontal tubular bar approximately 135 cm above the flooring and not more than 2 cm from the wall, placed at intervals of 20-40 cm.

Other requirements

If the rear wheelcases project into the floor-space, the casing must be squared off and the edges rounded. The wheelcases should either be made of wood or be covered with wood. For the transport of large cattle these wheelcases should be plated with iron not less than 0.5 cm thick.

Exceptions

For vehicles built or offered for inspection before 1 January 1951, small departures from the above-mentioned requirements may be permitted.

ANNEX 3

NETHERLANDS STANDARDS FOR TRANSPORT ABROAD BY RAIL OF SINGLE-HOOFED ANIMALS, HORNED BEASTS, SHEEP, AND HOGS

Wagons used for the transport of any such animals across any Netherlands frontier must comply with the following requirements :

1. The wagon should be capable of proper ventilation ; roofing must be watertight ; the wagon must be throughly cleansed and disinfected.

2. The floor should be undamaged ; no nail or other sharp obstruction should project from the floor or walls.

3. The consignor is responsible for providing a layer of pure sand to cover the floor to a thickness of not less than 2 cm ; no gravel or stone of any kind may be mixed in the sand. The floor must in addition be provided with an adequate layer of whole straw, peat-litter, or sawdust.

For the transport of hogs, the consignor is responsible for providing a layer of pure sand to cover the floor to a thickness of not less than 6 cm ; this layer of sand must be moistened with a mixture of water and two litres of vinegar per wagon during the period 1 June to 30 September of each year. In winter, the consignor is responsible for providing a 2-cm layer of pure sand and whole straw to cover the floor.

4. Where animals are expected to remain in the wagon for more than 24 hours after passing the frontier, they must be guarded. The attendant must, where possible, take his seat in the wagon near the animals at the station of consignment.

Injured animals may not be accepted for transport.

One attendant is required for a maximum of :

(*a*) 4 wagons carrying single-hoofed animals ;
(*b*) 3 wagons carrying cattle ;
(*c*) 3 wagons carrying sheep ;
(*d*) 3 wagons carrying hogs.

For the transport of cows requiring milking on the journey, a minimum of one milker attendant to every 15 cows is required, except where the consignor states in the bill of lading the stations at which a forwarding agent, assigned by him, will care for the animals ; express mention to this effect must be made in the bill of lading. The term " care " is understood to embrace feeding and watering, and milking where necessary.

For the transport of pregnant animals, the attendant should be seated in the wagon containing the animals.

Attendants should be experienced in respect of the kind of animal accompanied.

The route to be followed should be so chosen as to include stopping places (or stations) where feeding and watering may be carried out.

For single-hoofed animals and cattle, a minimum of 10 kg of hay per head should be available for every period of 24 hours between points of re-provisioning. For fat calves and sheep, every wagon should have at least two feeding or drinking troughs, depending on the number of animals to be carried, and sufficient fodder should be loaded for the duration of the journey.

5. For the transport of single-hoofed animals, where fastening is required, an effective halter attached to a strong and sound rope should be used.

The hind hoof-irons should always be removed to minimize possible damage from kicking.

Pregnant cattle and milch cows should always be fastened by means of an effective halter.

Cattle should be so fastened as not to hamper their lying down.

Bulls over the age of 13 months must be provided with nose-rings. As a rule, young calves should not be fastened during a journey. Where young calves and cattle are being carried in the same wagon, the two should be separated. Where single-hoofed animals, big and small cattle, and/or hogs are being carried in the same wagon, the different kinds of animals should be separated by partitions.

The same provision applies to animals of a different sex or kind to the extent that the kinds cannot conveniently be placed together.

This provision does not apply to nursing animals and their young. Where a wagon is fully loaded with hogs, nursing sows and their young should be separated from the rest by a partition.

ANNEX 4

NETHERLANDS REGULATIONS FOR OVERSEAS TRANSPORT OF ANIMALS

Article 1

Animals are defined as: horses, cattle, pigs, sheep, and goats.

Stables are defined as: stalls, cages, etc., wherein animals are conveyed.

Article 2

Licence for Animal Transport

1. No animal shall embark from a Netherlands or a Netherland Antilles port unless a licence for animal transport has been issued in respect of the carrier ship and the specific voyage.

2. This licence is issued only after current regulations are complied with.

3. The licence shall state the maximum number of horses, cattle, pigs, sheep, or goats to be transported on the scheduled voyage.

4. Application for the licence should be made by the consigner in writing to the Chief of Shipping Inspection.

5. The initial application should be accompanied by drawings and the requisite data regarding the construction, equipment, and crew of the ship, and the scheduled route.

6. In any subsequent application for a licence, alterations, if any, in the ship and in the scheduled route since the date of the initial application must be declared.

7. The licence for animal transport will be issued by the Chief of Shipping Inspection when the officials concerned are satisfied that the respective regulations have been complied with.

Article 3

Welfare of Animals

1. Every animal should have sufficient space to enable it to feed, drink, and rest during the voyage.

2. Horses and cattle should always be placed abeam.

3. Except with the special approval of the Inspector General of Shipping, animals may not be transported on those parts of the decks exposed to wind and weather.

4. Animals may not be transported in stables that are not directly installed on deck, with the exception of stables installed on hatches where due provision is made to prevent water, urine, and other waste matter from penetrating to the holds beneath.

5. The construction, arrangement, and finishing of the stables and the construction materials thereof must be approved by the Chief of Shipping Inspection.

Article 4

Space Requirements for Animals

1. Stables of the following dimensions are required for:

Horses

	Maximum	*Minimum*
Width	0.85 m	0.70 m
Breadth	2.45 m	2.15 m
Height	2.10 m	0.50 m above the height of the withers

Full-grown cattle

	Maximum	*Minimum*
Width	3.35 m	0.90 m
Breadth	2.75 m	2.45 m
Height		1.80 m above the height of the withers

Cattle not full-grown

	Maximum	*Minimum*
Width	3.35 m	0.70 m
Breadth	2.75 m	1.80 m
Height		1.60 m above the height of the withers

The above widths are measured fore and aft, while the breadths are measured abeam. For pigs, a maximum floor space of 6 m^2 is required. For sheep and goats, a maximum floor surface of 15 m^2 is required.

2. The maximum number of animals allowed per stable for every scheduled voyage is calculated as follows:

Horses, light or heavy	1
Cattle, live weight of 400 kg or more	4
Cattle, live weight under 400 kg	5
Pigs	4
Sheep and goats	15

In fixing these numbers, the following widths are allowed for each animal:

Heavy horses and cattle of 400 kg live weight or more	0.75 m
Heavy horses and cattle of live weight under 400 kg . .	0.60 m

Where a full-grown bull or cow is transported in one stall, the available width must be at least 0.90 m ; for a bull or cow not full-grown, a width of at least 0.70 m is sufficient. Every bull shall be housed in a separate stall. Stables for adult cattle may have a maximum height of 3 m where this is necessary. In determining the numbers to be carried, additional space must be allowed for heavy milking and pregnant cattle. In addition, the duration of the voyage and the destination of the animals should be taken into account.

Article 5

Transport of Pregnant Cattle

1. Pregnant cattle that may calve during a scheduled voyage must be so placed that ample space is allowed for parturition.

2. In conjunction with the Inspector of the Veterinary Service, the Chief of Shipping Inspection will estimate the number of stalls required for cattle which may calve during a scheduled voyage.

Article 6

Ventilation

1. Every hold to be used for the transport of animals must be provided with good artificial ventilation to promote the introduction of fully oxygenated fresh air and the withdrawal of foul stable air under all weather conditions.

2. For this purpose mechanically propelled fans must be installed, capable of forcing air into or withdrawing air from the hold. The capacity of the fans must be such that the air in the hold can be changed every three minutes under all weather conditions, allowing 70 m^3 of fresh air per hour for every full-grown horse or horned beast. At least one awning should be available for every hold destined for animal transport.

3. In the holds, animals must not be berthed nearer than 3 m to the outlet of the air ducts connected to the fans.

4. In covered and enclosed holds of steamships used for the transport of animals, an insulating air space of not less than 75 mm must be main-

tained between the boiler-room and the engine-room on the one side and the partition of the stable space on the other.

Article 7

Lighting

All decks across which animals are led or upon which animals are kept in stables must be provided with electric lighting. Lights should be installed at minimum intervals of 6 m ; not less than 40 watts per light should be provided.

Article 8

Gangways

A fore-and-aft gangway must be kept free between every two rows of animals and at every single row in order to ensure effective care of the animals under all weather conditions. Gangways for this purpose should be not less than 0.75 m wide, and free passage should be maintained at all times. In the extreme fore and extreme aft of the ship, the width of the gangway may be 45 cm. Where there are two or more fore-and-aft gangways in one hold, these must be connected by at least one gangway abeam of 0.50 m in width.

Article 9

Waste Outlets

Effective provision should be made for the discharge of urine and water from all decks used for the transport of animals. For this purpose, adequate outlets, waste-pipes, or scuppers must be provided. Free access to these outlets, waste-pipes, or scuppers should be maintained at all times. Waste-pipes to the bilges should be provided with a grating or filter to retain straw, hay, or other rubbish.

Article 10

Drinking-water, Food, and Bedding Materials

1. The ship must be provisioned with water and fodder in sufficient quantities to meet the animals' needs during the scheduled voyage, taking into account the possibility of unforeseen delay owing to bad weather or other causes. On the latter account, at least 10% should be added to the estimated consumption quantities in respect of a voyage of one week or longer, and at least 20% in respect of a voyage of shorter duration. Adequate watertight and covered storage-rooms should be available for fodder.

In fixing these numbers, the following widths are allowed for each animal :

Heavy horses and cattle of 400 kg live weight or more	0.75 m
Heavy horses and cattle of live weight under 400 kg . .	0.60 m

Where a full-grown bull or cow is transported in one stall, the available width must be at least 0.90 m ; for a bull or cow not full-grown, a width of at least 0.70 m is sufficient. Every bull shall be housed in a separate stall. Stables for adult cattle may have a maximum height of 3 m where this is necessary. In determining the numbers to be carried, additional space must be allowed for heavy milking and pregnant cattle. In addition, the duration of the voyage and the destination of the animals should be taken into account.

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The feeding and watering of the animals should be so carried out as not to cause them undue fatigue. Animals should be fed and watered at least once in the morning and once in the evening.

2. Provision of fresh drinking-water must be so arranged that, under all weather conditions and at every place where animals are berthed, there will be a supply sufficient to provide approximately 50 litres per horse or horned beast, and approximately 10 litres per pig, sheep, or goat, in every 24 hours. In determining the quantity of drinking-water to be carried, account should be taken of the possibility of replenishing or distilling supplies during the voyage. The fodder should be so stored that, under all weather conditions and at every place where animals are berthed, there will be a supply sufficient to provide, for each period of 24 hours, approximately:

10 kg of hay per horse or head of full-grown cattle
6 kg of hay per head of cattle not full-grown
1 kg of meal or $^1/_4$ kg of milk powder per calf below the age of 3 months
2 kg of meal per pig
2 kg of hay per sheep or goat

In determining the quantity of food to be carried, account should be taken of the possibility of replenishing supplies during the voyage.

Article 11

Fastening of Animals

1. Horses and horned or polled cattle should be fastened by the head during the trip in such a way that unnecessary harm or suffering is precluded. For the fastening of horses and horned cattle, strong pliable halters should be used.

2. Bulls should not be tied by the nose-ring in such a way that the ring will be strained by the animal when tugging at the halter rope.

3. The hind-shoes of horses and mules should be removed before the start of the voyage.

Article 12

Attendants

1. In addition to the ship's crew, experienced attendants should be available for the care of the animals to the number of at least one for every 30 horses or cattle or every 100 pigs, sheep, or goats. Where horned beasts

are being conveyed solely as deck cargo, one attendant to every 40 will suffice.

2. The Chief of Shipping Inspection shall fix the number of attendants where consignments do not form complete numbers as mentioned in paragraph 1 above.

3. Every consignment of animals shall be under the control of an experienced foreman, who will be responsible for the manner in which the attendants fulfil their duties and for the effective care of the animals in general. For a consignment of not less than 150 horses or horned beasts, the foreman should not be counted among the requisite number of attendants.

4. Where milch and freshly-calved cows are being transported, one experienced milker should be available per 15 cows. When transporting pregnant cows, some of the attendants should be experienced milkers.

5. Where a consignment of animals consists of not more than 5 horses or 10 horned beasts or 15 pigs or 30 sheep or goats, the care of the animals may be assigned to the crew provided that, in the opinion of the captain, this will not interfere with their other duties, and provided that none of the animals is expected to give birth during the voyage.

6. Attendants must not be accommodated in stables.

Article 13

Cleansing and Disinfection

All parts of the ship used for the transport of animals must, before embarkation, be effectively cleansed and disinfected to the satisfaction of the Chief of Shipping Inspection, in accordance with the advice of the Inspector of the Veterinary Service. During the voyage, all stables in which animals are berthed should be regularly cleaned. In the tropics, stables must be cleaned at least twice every 24 hours.

Article 14

Embarkation

1. Prior to loading, animals must be inspected by the Inspector of the Veterinary Service for the scheduled voyage, and authorization for their export issued.

2. During embarkation the consignor and the captain should ensure that animals are not stowed in the different stables in excess of the prescribed number and kind, as laid down by the Chief of Shipping Inspection under these regulations.

3. In embarking animals precautions should be taken against possible slipping on the gangways.

Article 15

Dispensary

Medicines and a first-aid outfit meeting the requirements of the Inspector of the Veterinary Service must be available on every ship carrying animals.

Article 16

Instruments for Slaughter

On every ship carrying animals, a pistol or revolver with the requisite ammunition must be available ; these weapons must be approved by the Inspector of the Veterinary Service. The captain is obliged to make these weapons available for inspection by the Inspector of the Veterinary Service, upon request. A sharp steel knife must be readily available for slaughtering animals in case of need.

Article 17

Spare Accommodation

The Chief of Shipping Inspection in conjunction with the Inspector of the Veterinary Service determines, in respect of every consignment of animals, the number of stables that must be kept available for sick or wounded animals.

Article 18

Transportation to the Tropics

Special arrangements are necessary for the transport of animals to the tropics.

ANNEX 5

DIRECTIVES FOR TRANSPORT OF ANIMALS BY AIR *

Only animals which are in perfect health and are well fed may be accepted for transportation.

Animals which are shortly going to give birth to young must not be accepted for transportation unless the owner signs a statement to the effect that he will bear all risks.

The animals must be delivered for shipment in suitable, i.e., solidly constructed, cases, crates, or cages.

The packing should be strong enough to prevent the animals from escaping *en route*.

The cases, crates, cages, etc., must be clean when they are put on board the aircraft. If necessary, they should be thoroughly cleaned before loading.

The containers need not be any larger than is strictly necessary, but they must be big enough to let the animal stand up or lie down ; it must also be possible to feed and water the animals while they are in the containers. The dimensions of the containers naturally depend on the type of aircraft used. Excessive dimensions may cause difficulty in stowage and transshipment.

Clear instructions about feeding must accompany all livestock presented for transportation.

The food sent along with the animals must be of good quality and should be stowed in a cool place if perishable.

When stowing, proper care must be taken to permit adequate draught-free ventilation ; animals must never be placed in a draught.

During high-altitude flights the animals must be stowed in pressurized freight compartments.

Stale air (inadequate ventilation) and excessive heat (the animals perspire and may subsequently catch pneumonia) must always be avoided because they raise the mortality rate.

Care must be taken to ensure that animals are not exposed to very strong sunlight.

The food must be stowed beside the consignment as far as possible, so that it is immediately available at intermediate airports.

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* Extracted from the directives for air cargo issued by K.L.M. (Royal Airways Company) of the Netherlands.

The cages, etc., must be loaded in an upright position.

In the case of animals requiring constant special attention, the consignment must be accompanied by an attendant. Unauthorized persons should not be allowed to approach the animals. The animals must always be kept as quiet as possible.

At each airport where there is a comparatively long stop, the animals must be placed in well-ventilated buildings or hangars.

Food must never be served direct from the refrigerator ; if food is short, extra supplies may be purchased, but the animals should not be overfed.

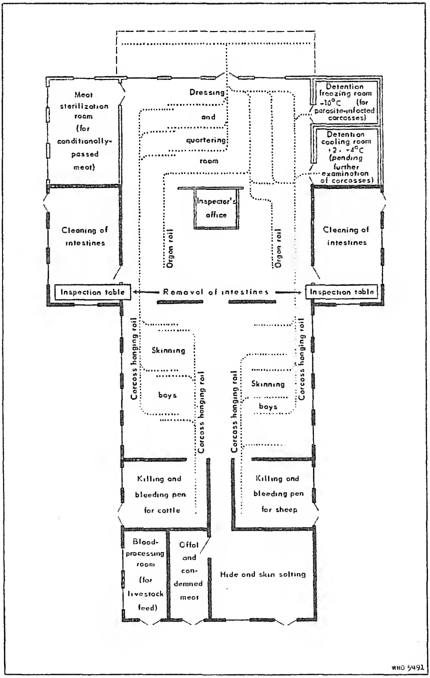
Should serious cases of illness occur during the flight, the next airport must be requested to have a veterinary surgeon on hand when the aircraft arrives.

ANNEX 6

DESIGN OF ABATTOIRS

The following charts (Fig. 1-3) are suggested designs of abattoirs incorporating the essential divisions of operations discussed in the

FIG. 1. SINGLE-LEVEL ABATTOIR WITH SEPARATE ROOMS FOR KILLING AND BLEEDING, SKINNING, AND DRESSING

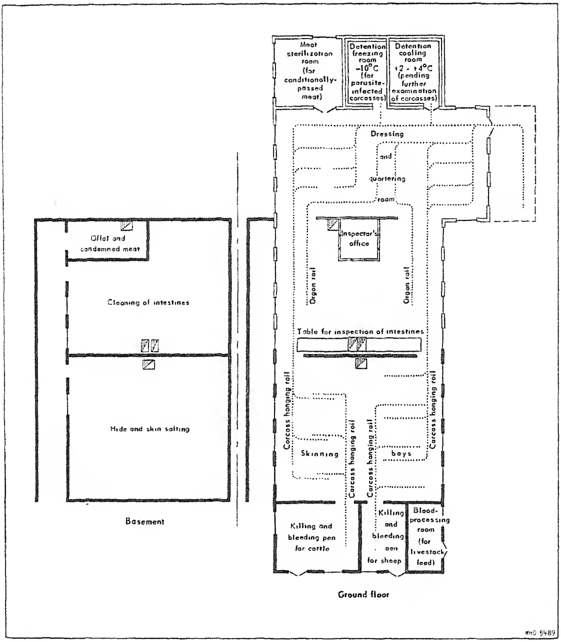


▬▬▬ *Unclean operation*

first report of the Joint FAO/WHO Expert Committee on Meat Hygiene.*

The design given in Fig. 3 is for a relatively simple construction suitable as a public abattoir made available to individual private meat dealers—a

FIG. 2. TWO-LEVEL ABATTOIR WITH SEPARATE ROOMS FOR KILLING AND BLEEDING, SKINNING, AND DRESSING



Unclean operation

A basement is provided under the abattoir for salting hides and skins, cleaning stomachs and intestines, and treating condemned material.

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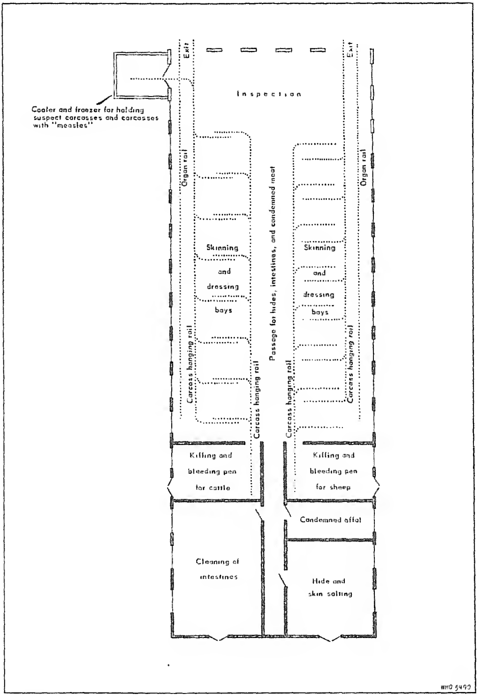
* Published as *Wld Hlth Org. techn. Rep. Ser.* 1955, **99**

practice common in many countries, including the less developed ones. For this type of abattoir, it is suggested that the killing and bleeding of the animals be performed by special personnel, while the skinning and dressing of the carcasses can be left to the private dealers. This would bring a desirable separation of the traffic of live animals, their slaughter and bleeding,

FIG. 3. SINGLE-LEVEL ABATTOIR WITH A SEPARATE ROOM FOR KILLING AND BLEEDING, BUT WHERE SKINNING AND DRESSING ARE DONE IN THE SAME ROOM



Unclean operation

from operations in the dressing bays. Mechanical hoists will be necessary in the slaughtering compartment for cattle, and skinning and dressing of the carcasses can take place partly on the floor if economic considerations preclude more-elaborate installations. In the sheep section, carcasses can be hung by hand and placed on individual loose benches for skinning and dressing. On-the-rail skinning and dressing of sheep has been successful principally in large abattoirs with a high daily turnover.

For designs of large abattoirs with highly mechanized installations, information can be obtained upon application by national authorities to the United States Department of Agriculture, Meat Inspection Service, Washington, D.C. Their publication *Information for Applicants for Federal Meat Inspection* (revised July 1952) contains detailed specifications on installations for abattoirs of various sizes.

ANNEX 7

FOOD-POISONING OUTBREAKS IN ENGLAND AND WALES, 1953, ASSOCIATED WITH PROCESSED AND MADE-UP MEATS

Type of meat	Presumed causal agents					
	Salmonella	*Staphylococcus*	*Clostridium welchii*	other organisms	agent not discovered	total
Cold meat (beef, mutton, veal, pork, and poultry)	9	3	4	1	9	26
Meat pies	9	2	6	0	9	26
Pressed meats	6	8	0	0	5	19
Ham, boiled bacon	0	11	0	1	4	16
Meats in gelatin	5	6	1	0	3	15
Sausages, liver sausages, and the like	5	3	0	0	5	13
Re-heated meat	5	4	8	0	7	24
Tongue	1	3	—	—	3	7
Canned meat (corned beef, luncheon meat, etc.)	0	2	0	0	4	6
Sandwiches	2	2	0	0	0	4
Stuffed meat	1	1	—	—	1	3
Various other meats	1	2	0	0	2	5
Total	44	47	19	2	52	164

ANNEX 8

SOME CHARACTERISTICS OF BACTERIAL FOOD-POISONING

Causal agent	Interval from ingestion of food to onset of illness	Reservoirs of the infecting organism	Types of food usually incriminated	Characteristic symptoms
Salmonella (food-poisoning types)	8-72 hours; often 8-12 hours	gastro-intestinal tract of animals	fresh meat .. 1 canned meat. 19 processed and made-up meats . 170 " meat " ... 20 other foods (not meat) 275 total... 485 *	abdominal pain; diarrhoea; nausea; pyrexia; sometimes vomiting; prostration
Staphylococcus	1-6 hours; often 2-4 hours	man (skin and nose, and cuts); animals	fresh meat .. 2 canned meat. 35 processed and made-up meats . 205 " meat " ... 7 other foods (not meat) 72 total... 321 *	salivation; nausea; vomiting; abdominal pain; prostration; diarrhoea; subnormal temperature; recovery in about 24 hours
Enterococcus	4-12 hours	gastro-intestinal tract of animals	processed meat ..... 2 other foods (not meat) 2 total... 4 **	abdominal cramps; diarrhoea; no prostration or pyrexia; rapid recovery
Clostridium perfringens (welchii)	8-22 hours	gastro-intestinal tract of animals	fresh meat .. 2 canned meat. 1 processed and made-up meats . 74 " meat " ... 4 other foods (not meat) 3 total... 84 *	abdominal cramps; diarrhoea; no prostration or pyrexia; rapid recovery
Clostridium botulinum	2 hours to 8 days; often 12-48 hours	soil	meat, mainly processed meat ..... 36 other foods . 426 total... 462 ** (In Europe, meat—and in the Far East, fish—is the commonest food associated with botulism)	difficulty in swallowing; double vision; no pyrexia; in fatal cases, respiratory paralysis

* Data obtained from reports on food-poisoning outbreaks in England and Wales, 1949-53, issued by the Public Health Laboratory Service of the Medical Research Council of Great Britain

** Data obtained from: Dack, G. M. (1949) *Food poisoning*, Chicago

ANNEX 9

SPECIMEN REPORTING-FORM FOR INVESTIGATION OF FOOD-POISONING OUTBREAKS *

(FRONT)

Date of onset of symptoms in first case ....

Investigator ....

Administrative area(s) .... No. at risk ....

No. affected ..... Fatal cases : No. ..... Age(s) ..... years Incubation period(s) .... hours

Characteristic symptoms : ....

Presumed causal agent .... Presumed vehicle (food) ....

History of food remnants (where stored and at what temperature) between time eaten and time examined :

Origin and preparation of food (ingredients, where bought and prepared, how stored, where consumed) :

Probable reservoir of infecting organism (include animal investigations) :

(*Please turn over*)

(BACK)

Details of laboratory investigations

	Number inves-tigated	Type of specimen	Number of specimens	Organisms isolated	Number of specimens positive	Number of persons or foods positive
Patients						
Food handlers						
Healthy persons at risk						
Foods						

Notes and comments :

* To be used for outbreaks involving two or more related cases or excretors

ANNEX 10

ISOLATION AND IDENTIFICATION OF PATHOGENIC BACTERIA IN CASES OF FOOD POISONING *

Food-poisoning outbreaks may be caused by one of a variety of etiological agents. Certain bacteria or their metabolic products are the most important of these agents.[8] A number of metallic compounds may produce poisoning. A few foods are inherently poisonous owing to the presence of alkaloids or of more obscure but perhaps related substances. The phenomenon of food allergy is also encountered. Finally, there are always a number of outbreaks in which no definite causative agent can be ascertained. At times the epidemiological evidence and clinical symptoms may afford important clues, but at other times this information is of little etiological assistance.

Since the methods to be presented here deal only with bacteriological examination, no attempt will be made to outline procedures for those instances in which food is poisonous from other causes. There is ample evidence, however, that at times other agents cause very striking cases or outbreaks, which may simulate bacterial food-poisoning. In this category are poisonings due to mushrooms or other fungi, the "milk sickness" following consumption of milk from cattle which have eaten white snakeroot or richweed, some forms of shellfish poisoning due to the presence of a toxic dinoflagellate in the shellfish,[33] and other animal or plant poisons conveyed directly or indirectly through food.[8]

When bacterial food-poisoning is suspected, the laboratory worker should bear in mind those micro-organisms which have been clearly implicated as the cause of previous outbreaks. The organisms against which the evidence seems definite are the following:

(1) *Clostridium botulinum*, whose toxin gives rise to clinical symptoms distinct from those produced by the other food-poisoning organisms;

(2) members of the *Salmonella* group;

(3) enterotoxin-producing strains of *Staphylococcus*;

(4) certain strains of *Streptococcus*;

(5) *Clostridium perfringens*;

(6) *Bacillus cereus*.

* By kind permission of the American Public Health Association, the information given in this annex has been taken from the chapter on bacterial food-poisoning to be published in the fourth edition of *Diagnostic Procedures and Reagents for Public Health Laboratories in Bacteriology, Mycology, Parasitology and Immunology*.

The chief concern must be to detect these organisms, but the possibility of finding some other significant organism should not be overlooked. The examination of suspected foodstuffs may be complicated because of the greatly diversified natures of the bacteria possibly involved ; but the laboratory worker is often spared much time when epidemiological and clinical data are available, since such information may narrow down the search for the causal agent. Some salient characteristics of various types of bacterial food-poisoning are given in Table I.

TABLE I. FEATURES OF FOOD POISONING CAUSED BY BACTERIA

Disease	Onset of symptoms	Type of food commonly involved	Symptoms and other characteristics
Botulism	6 hours to 8 days ; average 12-30 hours	Home-canned low-acid vegetables	Difficulty in swallowing, speech, and respiration ; double vision. Death from paralysis of muscles of respiration.
Staphylococcus poisoning	1 to 6 hours ; average 2½-3 hours	Processed meat, potato salad, cream-filled bakery products, dairy products	Nausea, vomiting, abdominal cramps, diarrhoea, and acute prostration and circulatory collapse in occasional severe cases. Usually no fever. No secondary cases.
Salmonellosis	5 to 72 hours	Poultry and poultry products, processed meat	Abdominal pain, diarrhoea, chills, fever, frequent vomiting, and prostration. Secondary cases may occur. Leukocytosis.
Streptococcus faecalis poisoning *Clostridium perfringens* poisoning *Bacillus cereus* poisoning	2 to 18 hours ; usually 11-15 hours	Ground meats, dressing Re-heated meats, meat pies, and pasties, cold meats, stews, and made-up dishes. Foods containing cereal products, e.g., vanilla pudding	Nausea, seldom vomiting, usually abdominal cramps and diarrhoea. Symptoms seldom persist longer than 8-12 hours. No secondary cases. Fever and prostration absent.

Collection of Specimens

Samples for laboratory examination must not be collected indiscriminately. Preliminary epidemiological investigation will reduce to a minimum the number of suspected foods in a given outbreak. Evidence concerning the particular foods most likely to be responsible should be sought by listing foods consumed by those made ill. While this evidence is not always clear-cut, at least a number of items can usually be eliminated. Some judgement may be called for in deciding what foods would be most likely

to have conveyed the various causative organisms or their toxins. The time when symptoms first appeared and other pertinent facts should also be recorded.

When food from sealed containers is under suspicion, obtain the original container wherever possible, together with the complete label of the product. Make a record of code marks and any other identifying marks on the container.

When it is necessary to transfer a representative sample to a smaller container, sterilized sample bottles should be used. If the samples are of such a nature that they cannot be put into the common sizes of sterile containers, they should receive every possible protection from additional contamination in transit.

Faecal specimens are often of value if secured early in the acute stage of the disease. Blood samples are of less importance, but may be useful in cases of botulism or occasionally in *Salmonella* infections, particularly where it has been impossible to obtain samples of the suspected foodstuffs. If necropsy material is available from fatal cases, samples of the stomach contents, as well as portions of the colon, spleen, and mesenteric lymph-nodes, should be collected.

It is important that all samples be collected promptly and that the laboratory examination be started without delay. If specimens must be shipped, arrangements should be made for their refrigeration before and during transit.

Botulism

CAUTION: Botulinum toxin is extremely dangerous and extreme precaution should be taken in handling suspected samples. Minute amounts of the appropriate types are lethal to man when ingested. Hence, in handling botulinic food-specimens, cultures, or filtrates, pipetting must *never* be done by mouth. The possible absorption of toxin through the conjunctiva or broken skin should also not be overlooked.

Make a Gram stain preparation directly from the liquid portion of the suspected foodstuff. If the food is solid (e.g., meat or fish) macerate a representative portion in sterile physiological saline, and examine the suspension after the larger particles have settled out. If the only sample submitted is an empty jar or can, the interior should be thoroughly washed out with a few millilitres of sterile saline or nutrient broth. The washings can then be used for the direct microscopic and cultural examinations. Unused remainders of food samples should be kept refrigerated in case additional tests are needed.

Test for toxin in food

The liquor from the foodstuff or original container, or a saline extract of the food, should also be tested for botulinum toxin, as described below. If a sufficient quantity of sample and the requisite facilities are at hand, Berkefeld or Seitz filtration may be desirable to eliminate bacteria. Otherwise, to lessen contamination and to avoid possible loss of toxin from adsorption on the filter, centrifuge the material, and use the supernatant for animal inoculation.

After preparing the material for animal tests by filtration or centrifuging, remove a small portion to a sterile test-tube and heat for 10 minutes in a boiling water-bath. This serves as a heat-labile toxin control.

Portions of the unheated sample and of the heated control should now be administered intraperitoneally to guinea-pigs or white mice. An alternative procedure, suitable for guinea-pigs only, is to feed portions of the sample from a pipette. This requires a somewhat larger sample, and is not as delicate a test for minute amounts of toxin, although it has the advantage of eliminating the occasional infections caused by bacteria in badly spoiled samples which were not previously filtered.

Inject one or preferably two mice intraperitoneally with from 0.1 ml to 0.5 ml of the filtered or centrifuged food sample, and inject either one or two mice similarly with equivalent volumes of the heated control sample. If guinea-pigs are used, inject intraperitoneally 0.5-2.0 ml of the test material; or feed 2-5 ml amounts. The doses given will be largely governed by the volume of sample available. If none of the test animals dies, proceed at once with enrichment cultures.

If the animals receiving heated controls survive, while those given unheated food samples die, specific neutralization tests should be carried out, using types A, B, and E botulinum antitoxins.* When these antitoxic sera are not on hand or cannot be promptly obtained, the material should be sent to a laboratory with the required facilities. When antitoxic sera are available, inoculate a group of mice or guinea-pigs with mixtures of the food sample and of types A, B, and E antitoxins, respectively. Use the same dose of food sample as in the foregoing test, and mix thoroughly in a syringe with 0.2 ml of the antitoxin. Hold each mixture for about 20 minutes at room temperature before injecting it intraperitoneally, to ensure full combination. Occasionally, if the serum is of low antitoxic

* Types C and D may be disregarded since they have not been implicated in human botulism. Types A and B toxins (the former more frequently in North America) are liable to be involved in outbreaks due to home-canned vegetables and fruits, and, less often, to meat products. The reverse holds in certain European countries, notably Germany and France. Type E toxin should be suspected when the vehicle is pickled or smoked fish or marine mammal.[16]

potency, while the food sample contains much toxin, larger amounts of serum may be needed to ensure neutralization. But if the serum has been preserved by the addition of 50% glycerol or of 0.5% phenol, confusion may arise from fatal reactions due to the preservative, when mice are injected intraperitoneally with 0.5 ml or more of the serum.

The condition of the animals injected with food specimens will afford evidence of the presence and type of botulinum toxin in the food. Given a toxin of high potency, the appropriate animals often succumb within a few hours, after displaying bellows-like respiration, constricted abdomen, and limb paralyses. Low potency toxin may cause flaccidity of the abdominal muscles with some dragging of the limbs. Then death may not occur for three or four days, or even longer; and sometimes obviously sick animals will completely recover. It must be borne in mind that when animals, especially white mice, have been injected with unfiltered material from food samples, death may be due to invasion of the animal body with contaminating bacteria rather than to botulinum toxin. This adds to the importance of the control animals receiving heated material and antitoxin mixtures. Again, mice occasionally die in convulsions within comparatively few minutes after being injected with a food extract. This should not be a source of confusion, since mice do not die in less than three to five hours after injection of very large doses of botulinus toxin.

Culture tests for Clostridium botulinum

Plating. With a loopful of the fluid sample, streak in succession two agar plates, using preferably blood agar prepared from meat infusion (C.M. No. 33*). If blood agar is not available, meat-infusion agar without blood may be used (C.M. No. 5a*). The plates are incubated under anaerobic conditions at 37°C for two to three days, after which they are examined for colonies of *Cl. botulinum*.** The suspected colonies are picked to beef-heart medium which has been heated and cooled before inoculation, and incubated for four days at 37°C. Mice are injected with centrifuged supernatant fluid from the meat cultures as a test for toxin, and, if death follows, typing with specific antitoxins should be carried out as described in the following paragraphs.

Enrichment cultures. Botulinum toxin may not be demonstrated in the foodstuff, especially if the sample submitted is scanty or otherwise unsatisfactory, even though the presence of the organism may be detected by

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* Refers to one of the formulae for culture media given in *Diagnostic Procedures and Reagents* (see footnote, page 390).

** These colonies may assume many forms, and long experience is needed for selecting them. On dry blood-agar plates, they are usually slightly haemolytic, small, flat, somewhat irregular in outline, fairly smooth in texture, and translucent. On moist plates, colonies tend to develop frond-like outgrowths, or only a thin continuous film of growth may be apparent.

enrichment, in appropriate media, of the sample or washings from the container. Sometimes very small scraps of the implicated food (e.g., a fragment of herring backbone retrieved from a garbage can) repay cultural examination. When a sufficient quantity of the food sample is available, inoculate 1-4 g (or ml) into each of three large tubes of ground-meat medium (C.M. No. 14*). Before inoculation, this medium should have been held in a boiling water-bath to expel air, and then cooled. Addition of 1% dextrose will facilitate growth of the anaerobe, and usually will promote toxin production by *Cl. botulinum*. The final pH should be 7.2 to 7.6 after autoclaving.

Immediately after inoculation of the meat medium, heat two of the three tubes in a water-bath at 80°C for 20 minutes to destroy bacterial vegetative cells. Leave the third tube unheated. These exposures to heat are arbitrary in degree and duration. If type E botulism is suspected, it should be borne in mind that type E spores are relatively heat-labile. On the other hand, advantage may have to be taken of the high thermal resistance of type A spores when attempting to isolate a suspected type A strain from material badly contaminated with other anaerobes. Incubate all three tubes anaerobically at 37°C for three to four days. If an anaerobe jar is not available, layer the tubes with sterile vaseline or agar to form a seal.

Examination of these cultures should supplement the foregoing direct test for toxin in the food sample. Note any macroscopic evidence of growth and prepare Gram stains from each tube. Note whether Gram-positive bacilli, with or without subterminal spores, are present. Select one or more tubes for a toxicity test similar to that carried out with the original sample. The result may confirm the test secured with the food sample, or may afford additional evidence when toxin cannot be demonstrated directly in the foodstuff. In the event of a positive test, the meat-medium cultures may be used for further purification and isolation of *Cl. botulinum* if this is desired.

Blood and bowel contents. In cases of botulism, toxin can sometimes be demonstrated in the blood or in the gastro-intestinal contents by animal injection together with the use of specific antitoxins. It is necessary to dilute the bowel contents with sterile saline solution, centrifuge, and filter through a Berkefeld or Seitz filter to get rid of the numerous contaminating bacteria which are present before using the specimen for toxin tests.

In cases of clinically typical botulism, the demonstration, by the above methods, of toxin in a foodstuff, or the procurement of toxic cultures therefrom, usually serves to designate the food responsible for the episode.

* Refers to one of the formulae for culture media given in *Diagnostic Procedures and Reagents* (see footnote, page 390).

Use of type-specific antitoxic sera may furnish additional information as to the specific type of *Cl. botulinum* involved. However, a reservation applies here to instances in which a culture of *Cl. botulinum* has been isolated from an empty discarded container, when none of the suspected foodstuff remains for direct testing for the presence of toxin. Such a finding may be very significant, but it should be recalled that botulinum spores occur in soil, and might conceivably have gained entrance to the empty container after it was discarded. Any conclusions drawn from such findings must therefore take into account the conditions to which the container was exposed after first being opened. Similar arguments would apply to the isolation of a culture of *Cl. botulinum* from the gastro-intestinal tract, in the absence of demonstrable botulinum toxin of homologous type in the stomach or lower-bowel contents.

Staphylococcus

The ability to produce enterotoxin is apparently limited to coagulase-positive staphylococci.[6, 19, 20, 23] These organisms represent a homogeneous, readily identifiable taxonomic entity.[20, 29] However, not all coagulase-positive strains produce enterotoxin.[13, 19] Thus, considerable caution must be used in interpreting the results of bacteriological examination of a food suspected of being the vehicle in a food-poisoning outbreak. Careful correlation with the epidemiological and clinical features of the episode is especially important. The significance of laboratory findings is also dependent on the history of the food samples examined.[8]

The laboratory examination should involve quantitative plating in suitable media and a direct microscopic examination of Gram-stained preparations from each sample. Emulsify a 10-gram representative sample in 90 ml of sterile water in a sterile metal laboratory blender-cup. A Gram stain and further dilutions for plating should be made from the emulsified specimen. Streak plates of blood agar (C.M. No. 33*) and inoculate the surface of salt-mannitol agar with 0.05 ml of decimal dilutions of the food.

There is no completely satisfactory selective medium for the enumeration of coagulase-positive staphylococci. However, *Staphylococcus* medium No. 110 and the Chapman-Stone medium are also useful[4, 5, 26] despite the fact that coagulase-negative micrococci and occasional strains of the genus *Bacillus* may grow luxuriantly on them. Pick representative colonies and make the coagulase test using a suitable plasma such as Bacto-Coagulase plasma.[11]

From a practical standpoint it would seem desirable to consider any food found containing large numbers of coagulase-positive staphylococci

* Refers to one of the formulae for culture media given in *Diagnostic Procedures and Reagents* (see footnote, page 390).

(5×10^5 per gram) unfit for human consumption. Although such findings prove nothing in a medico-legal sense, they would represent good presumptive evidence that the food had been grossly mishandled at some time prior to laboratory examination and might well contain enterotoxin.

The finding of small numbers of coagulase-positive staphylococci in a food should not be considered particularly significant, but if such a food were inadequately refrigerated it might become dangerous. Fortunately, these organisms cannot grow appreciably or produce enterotoxin at temperatures below 50°F (10°C). The presence of large numbers of coagulase-negative micrococci in a food sample may be indicative of mishandling at some previous time, but there is no evidence that consuming the food would have any effect on the well-being of the consumer.

There is, however, the complicating fact that, in a heated food, the staphylococci may have been killed without destruction of their enterotoxin. The appearance of large numbers of Gram-positive cocci in the stained preparations might be expected in such a situation. This also serves to re-emphasize the importance of careful consideration of the epidemiological and clinical features of the episode under investigation.

The only completely reliable test for the responsibility of a suspected food is to feed it to a group of human volunteers. This practice is not recommended. Therefore, when large numbers of coagulase-positive staphylococci are found in the food, for further evidence of their implication one must resort to examination of some of the isolated pure cultures for their ability to produce enterotoxin.

Several methods for detecting enterotoxin in culture filtrates have been proposed. Feeding tests on monkeys are subject to fewer errors than tests involving the intraperitoneal or intravenous injection into monkeys or kittens, but monkeys are known to be more resistant to enterotoxin than man, and may develop a resistance to enterotoxin if used repeatedly (M. J. Surgalla & G. M. Dack, unpublished data). Also, monkeys are difficult to work with and relatively expensive. Therefore, injection of suitably prepared filtrates into kittens or cats may be the method of choice for the routine diagnostic laboratory. Care must be exercised to remove or neutralize other staphylococcal toxins that interfere with injection tests for enterotoxin.[12, 14, 17, 18] When properly applied these tests are sensitive and reliable.

Preparation of filtrates

Dolman & Wilson[17] found a semi-synthetic soft agar medium (C.M. No. 17*) satisfactory for the production of enterotoxin. Distribute the medium in shallow layers in Petri dishes, flasks, or bottles, and when cool

* Refers to one of the formulae for culture media given in *Diagnostic Procedures and Reagents* (see footnote, page 390).

seed the surface evenly with a few drops of a young culture of the staphylococcus under study. Incubate at 37°C for 40 hours under an atmosphere of 30% carbon dioxide and 70% oxygen. Squeeze the cultures through cheesecloth and centrifuge at high speed. Decant the supernatant fluid and sterilize where necessary by passing through a Seitz filter.

Monkey feeding tests

If available, *Macaca mulatta* may be used for feeding tests. The supernatant fluid from cultures prepared as outlined above may be fed without heating or filtration. Give 50 ml by stomach-tube to each of three monkeys. Observe the animals for vomiting over a period of six hours. If enterotoxin is present, vomiting usually occurs in 2½ to 3 hours. Monkeys may develop a tolerance upon repeated feeding, and it is necessary to test with known enterotoxin those animals which fail to react in order to eliminate from future tests naturally resistant animals or those that have developed a tolerance.

Preparation of filtrates for intravenous or intraperitoneal injection

Before a staphylococcus culture can be subjected to the kitten or cat test, it must first be Seitz-filtered, and then treated for elimination of the α and β toxins. For routine diagnostic laboratory procedure, heat the filtrate, adjusted to pH 7 by the addition of dilute acetic acid, in a boiling water-bath for 30 minutes. Remove any precipitate by centrifugation and use the supernatant for the injections. In most instances, this heat treatment will inactivate the α and β haemolysins, while the relatively heat-resistant enterotoxin survives in sufficient proportion to affect the test animals. However, considerable losses of enterotoxin occur when filtrates are heated to boiling for 30 minutes, and although the majority of food-poisoning strains produce enterotoxin of sufficient potency and heat stability to give positive reactions on injection, a negative reaction under such conditions would not necessarily indicate the absence of enterotoxin from the filtrate before boiling.

Haemolysins may be inactivated also by formolization or by neutralization with specific antitoxins. Where the latter procedure is followed, the antitoxin employed must be free from enterotoxin-neutralizing antibody. Although these procedures are less simple and more time-consuming than boiling, they are to be preferred when filtrates weak in enterotoxin content are being studied. Treated filtrates should be warmed to 37°C before injection and should be administered slowly by either route.

Dolman [15] noted that a strain of *Staphylococcus* produced potent enterotoxin, but only negligible amounts of α toxin when grown on the above medium for 3½ days in air at room temperature. Filtrates of cultures thus

grown could be injected into cats without further treatment. This simplified method is not necessarily applicable to all enterotoxigenic strains, but is worth trying.

Intravenous injection

Only healthy adult cats should be used. A moderate-sized meal given shortly before inoculation of the enterotoxin has been found to increase the effectiveness of the vomiting stimulus, while refusal of an offered meal aids in the elimination of sick animals. Inject treated culture filtrates slowly into the saphenous vein at about the level of the knee. According to the potency of the toxin, 0.5-5 ml may be required.

Intraperitoneal injection

Kittens from 6 weeks to 3 months of age and weighing 350-700 g are most satisfactory for the test, but young cats weighing up to 1 kilogram may be used. Three millilitres of the treated filtrate are injected intraperitoneally. If no reaction occurs, 5 ml of the filtrate should be given.

Results of injection tests

The characteristic syndrome produced by injection of enterotoxic filtrates is marked lassitude and apathy, followed by one or more bouts of retching and vomiting, often associated with diarrhoea, over a period of 30 minutes to 4 hours after administration. Repeated use of test animals is not desirable as an increased tolerance to the enterotoxin may develop.

Streptococcus

Streptococci have been implicated as the etiological agent in a number of food-poisoning outbreaks.[1, 2, 3, 24] The cultures from these outbreaks which have been carefully studied were found to be confined to the enterococcus group, specifically *Streptococcus faecalis*.[1, 9, 31, 32]

Only a few instances are recorded in the literature in which the *Streptococcus* isolated from the incriminated food has been fed to human volunteers in pure cultures to confirm its toxigenic capacity. Human volunteers provide the only known acceptable means of testing the ability of a *Streptococcus* strain to induce food-poisoning symptoms in man. Consequently, for the great majority of the reported food-poisoning outbreaks in which enterococci have been implicated, the evidence is largely circumstantial, being limited to the alleged symptoms of the illness, the time of onset, the presence of large numbers of enterococci in one or more of the foods

consumed, and the apparent absence of other known food-poisoning micro-organisms in the samples examined.

The symptoms ascribed to enterococcus food-poisoning are similar to those of staphylococcus food-poisoning, although usually less severe.[8] While diarrhoea occurs, neither uncontrollable vomiting nor acute prostration is characteristically present. The time of onset may vary from 2 to 18 hours after eating the food.

Since enterococci are normally found in large numbers in the intestine of man and animals, it would appear that only rare strains, growing under special conditions, are capable of causing food poisoning. Thus far, no physiological or serological differences between the streptococci implicated in food poisoning and the so-called "typical" enterococci have been detected. Obviously, the examination of stool specimens from afflicted persons for the presence of enterococci would yield no helpful information.

The available evidence to date indicates that very large numbers of viable enterococci (10 000 million or more) must be ingested at one time to produce symptoms. In contrast to the staphylococcal food-poisoning situation, culture filtrates or heat-killed cultures do not give rise to symptoms. It is unnecessary, therefore, and may be misleading, to employ enrichment culturing methods for the detection of enterococci in suspected foods. Such procedures do not indicate the total numbers of enterococci present in the food.

Direct smears, preferably Gram stained, should be prepared from several portions of the food and examined for the presence of large numbers of streptococcus-like micro-organisms. Aliquots of the food should be plated quantitatively on blood agar or on a suitable medium containing glucose. In most instances, the results of the direct microscopic examination will suggest the appropriate dilutions to be made.

The finding of large numbers of cocci in pairs or short chains in the smears made directly from the foodstuff, or large numbers of streptococcus-like colonies on the culture plates, may possibly have significance. However, considerable caution is necessary in interpreting these findings. If the food material has been subjected to conditions which favour salivary contamination, one should expect α-type streptococci to develop on the blood-agar plates. Also, some fermented foods, such as cheese, certain varieties of sausage, and fermented milk-drinks contain indigenous streptococci and other lactic acid bacteria that may cause confusion to the laboratory worker. In such instances, no significance should be attached to their presence.

A selective plating-medium for the quantitative detection of enterococci would be desirable in the examination of suspected foods. A foolproof medium of this nature is not yet available, but one which has met with

partial success was proposed by White & Sherman [34] and modified by Dack et al.[9] This medium consists of 0.5% glucose, 0.5% tryptone, 0.5% yeast extract, 1.5% agar, 0.01% sodium azide, and penicillin in a concentration of 100 Oxford units per litre (added to the sterilized medium before plating). Most of the enterococci grow quantitatively on this medium after incubation for 48 hours at 37°C. An occasional colony of a *Lactobacillus* may also grow.

Where large numbers of streptococci which appear to be enterococci are encountered, several colonies should be picked and an attempt made to identify the resulting cultures. Their enterococcal identity can be established by serological methods if Lancefield group-D serum of known potency and specificity is available. Moreover, members of this group are among the easiest of the streptococci to identify by certain physiological and biochemical tests. They will grow in glucose broth at 10°C (observe after 7 days) and at 45°C, and also in a glucose/tryptone/yeast-extract broth containing 6.5% sodium chloride. Although few other streptococci possess this combination of characteristics, confusion with certain *Staphylococcus* and *Leuconostoc* species must be guarded against. Failure to yield a positive catalase test, and the inability to produce visible quantities of carbon dioxide from glucose, will further confirm their identity. To determine carbon dioxide production from glucose, the broth may be layered with a paraffin-petroleum jelly seal, or the method of Williams & Campbell [35] may be employed.

Other tests of proven value as practical and convenient aids for identifying enterococcus strains have been summarized by Sherman.[30]

Bacillus cereus

Hauge [21] reviewed the literature on the occurrence of aerobic, spore-forming, Gram-positive bacilli in foods implicated in food-poisoning outbreaks. Over the period October 1947 to October 1950, Hauge studied 4 large food-poisoning outbreaks caused by *Bacillus cereus* which involved about 600 people. Christiansen, Koch & Madelung [7] described an outbreak due to pudding, involving 15 out of 18 adults and 106 out of 136 children.

Bacillus cereus food-poisoning is characterized by an incubation period varying from 8 to 16 hours, but usually 12-13 hours. The symptoms are nausea (seldom vomiting), abdominal cramps about the umbilicus, tenesmus, and frequently diarrhoea. After about 4-6 bowel movements, the symptoms subside, usually within 6-12 hours. Fever is generally absent. The foods involved in *B. cereus* outbreaks have been vanilla-sauce powder and similar foods, prepared a day in advance, and generally stored under

conditions which permitted growth of *B. cereus*. *Bacillus cereus* is often found in corn or potato starch, which is an ingredient of vanilla-sauce powder.

Laboratory procedure

The Gram stain of the suspected food should show large numbers of Gram-positive, rod-shaped organisms. Where quantitative blood-agar plates are prepared there should be a preponderance of strongly haemolytic colonies of an aerobic, spore-forming bacillus appearing after 24 hours' incubation at 37°C. Stool examinations may show few colonies of *B. cereus* and are not recommended. In implicated foods, *B. cereus* has usually been found to number millions of organisms per gram.

Clostridium perfringens

Clostridium perfringens has caused outbreaks of mild illness characterized by abdominal cramps and diarrhoea, usually without vomiting, commencing 8-20 hours (average 10-12 hours) after eating contaminated food.[22, 25, 27, 28] Recovery from the illness is usually complete within 24 hours of the onset. Hobbs et al.,[22] in a study of outbreaks of *Cl. perfringens* food-poisoning occurring in Great Britain, found that the strains of the causative organism were feebly toxigenic, produced heat-resistant spores, and fitted into the type A group. Some differences are reported in the colonial characteristics [22] of the strains of *Cl. perfringens* isolated from food-poisoning outbreaks. In the outbreaks reported by McClung,[25] Osterling,[28] and Hobbs et al.,[22] the meat involved had been insufficiently cooked to destroy the spores and was kept long enough after cooking to permit growth of the organisms.

When meat cultures of living micro-organisms were fed to human volunteers, McClung,[25] Osterling,[28] and Hobbs et al.[22] observed similar symptoms to those occurring in food-poisoning outbreaks where *Cl. perfringens* appears to have been involved. On the other hand, Dack et al.[10] failed to cause illness in human volunteers fed strains (from food-poisoning outbreaks) of *Cl. perfringens* grown in veal-infusion broth containing 0.1% agar and 0.25% glucose, or in autoclaved chicken broth. It may be that the whole-meat cultures are necessary to cause illness. All investigators agree that filtrates do not cause illness when fed to human volunteers.

Laboratory procedure

Clostridium perfringens should be sought by laboratory examination if the epidemiological study of an outbreak points to a specific meat item as

the possible causative agent. The incubation period from the time of ingesting the food to the onset of illness will not differentiate *Cl. perfringens* food-poisoning from that caused by *Streptococcus faecalis* or *Bacillus cereus*, or from some outbreaks of *Salmonella* infection. A Gram stain of the implicated food specimen may prove helpful in showing a preponderance of Gram-positive, rod-shaped organisms. Prepare quantitative blood-agar plates with the food specimen unheated. Incubate the plates anaerobically at 37°C for 24 hours. If large numbers of non-haemolytic colonies resembling *Cl. perfringens* are found in the absence of significant numbers of *Streptococcus faecalis*, *Bacillus cereus*, or *Salmonella*, then significance may be attached to *Cl. perfringens* as the causative agent. According to Hobbs et al.,[22] if the anaerobic plates after examination are left aerobically at room temperature for 24 hours, the aerobic colonies will develop, making it easier to recognize the anaerobic *Cl. perfringens* colonies. The cultures may be tentatively identified as *Cl. perfringens* by biochemical reactions. Acid and gas are produced from glucose, maltose, lactose, and saccharose, but not from mannitol or salicin. Acid and a clot are formed in litmus milk incubated at 37°C for 24 hours. Anaerobic conditions may be obtained by boiling and cooling these differential media before inoculation and incubating the cultures in an anaerobic jar, or by sealing the cultures with sterile vaseline immediately after inoculation.

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ANNEX 11

ENTERIC INFECTIONS CAUSED BY SHIGELLA AND SALMONELLA *

Control of enteric infections is an acknowledged major responsibility of public health. The isolation and identification of enteric pathogens and the serologic examination for evidence of typhoid fever have been basic tasks of the public health laboratory. The earlier and simpler procedures seemed adequate to aid in the clinical diagnosis of typhoid fever, but now more exacting procedures are required in the search for carriers and in attempts to obtain etiological diagnoses of the prevalent, but ordinarily brief, diarrhoeal disorders which cannot be differentiated by clinical findings alone.

The bacteriological studies required commonly involve three steps, which may be carried out in one laboratory or in different laboratories. Isolation and presumptive identification, the first step, is designed to provide an early report useful as an aid in clinical diagnosis or as a guide in control. In general, these examinations are performed best in laboratories close to the patients, individuals, or animals being examined. Fresh specimens are essential for dependable observations for shigellosis, and are preferable for other examinations in enteric bacteriology. The second step in examination is the more detailed bacteriological study required for identification and for specific typing of the organisms. It involves the study of microorganisms that suggest, but do not exactly fulfil, the criteria for identification of recognized bacillary incitants of enteric disease. This may be, and ordinarily is, performed in a central laboratory. Thirdly, the assistance of a reference laboratory may be required for the identification of problem organisms or for specific typings.

Enteric infections are caused by a wide variety of organisms with differing culture requirements.** The isolation of the pathogenic types of *Escherichia coli* or of the cholera vibrio requires techniques which diverge widely from those used in the study of salmonellosis and shigellosis. Current techniques for *Shigella* and *Salmonella* have varying sensitivity for the different organisms involved. Thus, before beginning an examination

* By kind permission of the American Public Health Association, the information given in this annex has been taken from the chapter on bacterial food-poisoning to be published in the fourth edition of *Diagnostic Procedures and Reagents for Public Health Laboratories in Bacteriology, Mycology, Parasitology and Immunology*.

** See also Annex 10, page 390.

of enteric infections, it is essential that adequate information be provided to guide the bacteriologist in selecting procedures of highest promise in the particular case or situation.

It is readily acknowledged that in the hands of experienced workers alternative techniques may provide equally dependable findings. The procedures outlined are those believed to be preferable for the great majority of public health laboratories. They diverge from the multiple tests which are an accepted part of studies in descriptive bacteriology. The preferable public health practice is to arrive at the accurate conclusion in the shortest possible time with every practicable economy in glass-ware, media, and labour. Only in this way can there be maximum service from funds available.

Specimens

Faeces

Faecal specimens for culture may be obtained as follows:

(1) *Passed specimens*. In hospitals, the patient may be provided with a recently sterilized bed-pan and the whole specimen or a portion thereof should be taken to the laboratory without delay. In public health laboratory practice, these specimens ordinarily are submitted by mail, using one-ounce screw-capped bottles, half filled with a buffered 30% glycerol in normal saline solution with phenol-red indicator. About 1 gram of solid, or 2 to 3 ml of liquid, faeces should be added. The mailing container employed must meet the requirements of the postal regulations for the shipment of infectious material. Passed specimens are preferred in examining for *Salmonella*, particularly in the search for carriers, since large inocula are indicated.

(2) *Rectal swabs*. If the individuals to be examined are conveniently available, the faecal specimen for culture may be collected by rectal swab.[9] This is particularly recommended for examinations for shigellosis and in the testing of infants with acute diarrhoeal disease. In the young, the ordinary cotton-tipped applicator may be readily inserted beyond the anal sphincter and a suitable inoculum collected by rotating the swab and swinging it gently in a circular motion. In adults, the use of a lubricated rubber tube with the applicator inside facilitates the insertion of the swab. The major advantages of the rectal swab are that the specimens may be obtained as desired, assuredly fresh material is available for the inoculation of culture media, and the handling and disposal of faecal specimens is avoided. When the inoculum is collected by rectal swab, it is recommended that the media be taken to the bedside and planted immediately — otherwise the swab must be taken at once to the laboratory.

(3) *Sigmoidoscopic swabs*. Swabs taken during sigmoidoscopic examination from areas of maximum pathology in the lower bowel are significantly, but not markedly, superior for the isolation of *Shigella*.[7]

Urine

Urine specimens have some value in studies for the identification of carriers of *S. typhosa*. Passed specimens collected in such a way as to limit extraneous contamination are satisfactory. These may be mailed after adding equal amounts of urine to the glycerol-saline preservative.

Blood

Clotted venous blood collected under aseptic conditions is acceptable. The separated serum may be used for serological tests in possible *S. typhosa* infections, and the macerated blood clot may be cultured for *Salmonella* and certain other organisms. More-reliable blood cultures are obtained when 100 ml of an appropriate medium is inoculated directly with 10 ml of freshly drawn blood.

Bile

In the specific examination for typhoid carriers, duodenal drainage may be indicated. The criteria for judging the suitability of duodenal drainage material for bacteriological examination have been outlined by Forsbeck & Hollon.[5] Gall-bladders removed surgically may also be submitted for examination for *S. typhosa*.

Isolation and Presumptive Identification

Media selection

In examining for *Shigella* and *Salmonella*, the following culture media are of major importance :

Shigella Salmonella (SS) agar. This is used for initial plating. It inhibits most coliforms but permits the growth of most *Shigella* and *Salmonella* encountered in public health laboratory practice.

Wilson and Blair's bismuth sulfite (WB) agar. This is primarily for isolation of *S. typhosa*.

Enrichment broth, either tetrathionate brilliant-green, or selenite F, is useful primarily for *Salmonella*.

Brilliant-green (BG) agar. This is recommended for plating from the enrichment broth and is useful primarily for *Salmonella* other than *S. typhosa* and *S. paratyphi A*.

Different combinations of media are indicated for varying purposes. For studies of acute diarrhoeal disease for *Shigella* and *Salmonella*, one plate of SS agar and the enrichment broth subcultured to one plate of BG agar (or to SS, or even to both) is an effective combination. Some recommend that this be supplemented by at least one plate of a less inhibitive enteric medium (as eosin methylene-blue (EMB), MacConkey or desoxycholate agar). In the testing of food handlers for the detection of chronic carriers of *S. typhosa* one heavily inoculated streak-plate of WB agar is of the greatest importance. This may be supplemented by a pour-plate. (The practice of making enteric culture examinations from food handlers has been dropped in many areas.) When searching specifically for *Shigella*, as in epidemic situations, one well-inoculated plate of SS agar gives excellent results. This permits large numbers of examinations to be carried out. The enrichment broth and BG agar are particularly effective for the isolation of *Salmonella* other than *S. typhosa*. Where no information is at hand, an acceptable procedure is to use SS agar, WB agar (streak), enrichment broth, and BG agar for subculturing, thus using three plates and one tube for the initial isolation.

Inoculation

One should obtain a good distribution of isolated colonies over a major portion of the whole plate by any technique which will accomplish this. The following procedures are suggested:

For inoculation of SS agar, employ sterile cotton-tipped swabs. If the specimen is collected by rectal swab, the plate is inoculated directly from the swab. If material is submitted in glycerol-saline solution, the swab is dipped into the faecal mixture. The initial swab is used to streak from a quarter to a half of the plate. It is employed also to inoculate WB agar and the enrichment broth. A second sterile swab is used to cross-streak half of the SS plate (inoculating half of the uninoculated area by streaking through half of the heavily inoculated area). The remaining uninoculated area is streaked with the same swab without touching the other inoculated areas. By experience, one must learn the maximum amount of material which can be inoculated to SS agar in order to provide a desirable number of well-isolated colonies over a substantial portion of the medium. The amount of inoculum will vary materially, depending on the population under study. When examining young infants, for example, the plates must be lightly inoculated, otherwise there will be much overgrowth.

The WB medium should always be heavily inoculated. Redip the initial swab into faecal suspension and streak half of the plate. Complete the inoculation with the second swab used in spreading the inoculum on the SS agar, and spread the inoculum on WB as described for SS agar. When searching for carriers of *S. typhosa*, a pour-plate of WB may also

be used. For this, Edwards & Ewing recommended as the inoculum 5 ml of a heavy suspension of faeces.[3] The medium, melted and cooled to 45°C, is poured into the Petri plate in which the inoculum has been placed; the plate is then rotated gently to mix and distribute the inoculum evenly.

The tube of enrichment broth is inoculated by dropping into the tube the initial swab used for plating purposes. With shipped specimens the swab is first redipped into the faecal suspension to increase the faecal inoculum.

The brilliant-green agar plates are inoculated from the enrichment broth with a sterile wire loop approximately 5-6 mm in diameter. This is streaked to obtain areas of heavy, medium, and light inoculation.

All media other than WB may be examined after approximately 20 hours' incubation; the WB requires 48 hours' incubation before final reading. A second reading of SS agar plates at 48 hours is valuable for the detection of slow-growing strains.

Fluid or semi-fluid medium inoculated with blood should be plated after 24 hours, 48 hours, 1 week, and 2 weeks.

Picking colonies

The most important and difficult step in isolation of enteric pathogens is the picking of colonies. A suitable source of light is essential. The Quebec Colony Counter provides a good quality of artificial light, a dark background, and desirable magnification. Its use should be considered, but the preference of the individual experienced worker can determine the most desirable arrangement. In picking, time and energy may be saved by arranging conveniently the materials needed; it should be an unbroken rule to pick plates in serial order as this is the best assurance against errors in numbering.

The character of the colonies on the three different media is given in Table I.[6] There is no substitute for experience in learning the selection of suspect colonies. Workers must be encouraged to pick freely, preferably two or more of each type of suspect colony. Even those who are very experienced must finally rely on differential tube medium to separate the "negative" from the possibly "positive" colonies.

It is emphasized that on the surface of all highly selective enteric media, there may be viable organisms which have not grown. To assure picking pure cultures, only the elevated central surface of a colony should be touched. A scooping motion, with the needle sweeping the surface of the agar, is to be avoided.

All suspect colonies are picked to triple-sugar iron (TSI) agar (or Kligler's iron agar with 1% sucrose added). The inoculation is performed by stabbing the centre of the butt to its bottom, and by a final streaking of

TABLE I. CHARACTER OF GROWTH OF ENTERIC ORGANISMS ON SELECTIVE PLATING MEDIA

Group of micro-organisms	Shigella Salmonella (SS) agar	Plain desoxycholate, MacConkey's, or eosin methylene-blue agar (EMB)	Bismuth sulfite Wilson-Blair (WB) agar	Brilliant-green (BG) agar
Shigella	Colourless, some slightly pink; translucent, varying to transparent or to moderate opacity; round; raised; 1- to 5-mm diameter, some larger. *S. sonnei* may be large, flat, and irregular.	Colourless; transparent, 2- to 7-mm diameter; generally round. *S. sonnei* may be large, flat, and irregular.	Large, inhibited, occasionally develop as small colourless or greenish colonies with depressed centres	No significant growth
Salmonella typhosa	Similar to *Shigella*	Similar to *Shigella*	Isolated surface colonies; black, with surrounding brownish-black zone; a characteristic metallic sheen by reflected light. With congested growth; small, light green, often with darker centre. Sub-surface colonies; jet black, well-defined; no sheen. Size 1-4 mm.	Largely inhibited
Salmonella group (other than *S. typhosa*)	Similar to *Shigella*; occasionally some darkening of centre of colonies	Similar to *Shigella*	Variable; many types markedly inhibited, a few simulate *S. typhosa*, others develop as flat greenish to brownish colonies	Isolated surface colonies, pink to fuchsia surrounded by red medium, occasionally brownish with little change in medium
Alkalescens-dispar group	Similar to *Shigella*; tend to be more opaque	Similar to *Shigella*	Light to dark green, smooth, glistening	Largely inhibited; rarely may simulate *Salmonella* group

Group of micro-organisms	Shigella Salmonella (SS) agar	Plain desoxycholate, MacConkey's, or eosin methylene-blue agar (EMB)	Bismuth sulfite Wilson-Blair (WB) agar	Brilliant-green (BG) agar
" Coliform-aerogenes groups "	Largely inhibited ; pink to red ; opaque ; may be mucoid ; size variable	On desoxycholate and MacConkey's : red ; opaque ; on EMB : characteristic sheen by reflected light ; 2- to 7-mm diameter ; may be mucoid with dark centres	Quite marked inhibition ; some develop as dark, brown, or greenish colonies	Largely Inhibited ; may be yellowish-green
Proteus group	Growth in discrete colonies ; colourless, some with black centres, transparent to water-clear ; irregular edge	Often a spreading growth on EMB or MacConkey's ; usually discrete colonies on plain desoxycholate ; may simulate *Shigella* or *Salmonella*	Marked inhibition ; some green with darker centres	Largely Inhibited ; may be small reddish colony
Paracolon groups	Variable ; may be similar to *Shigella* or may approach coli-aerogenes group	Variable ; may be similar to *Shigella* or may approach coliforms	Similar to coliform group	Similar to coliform
Pseudomonas group	Variable ; usually colourless, often greyish-brown	Variable ; may simulate *Proteus*	Variable	Pink to purplish ; irregular edges ; may closely simulate *Salmonella* group

the slanted surface. Suspect colonies from pour-plates of bismuth sulfite agar should be picked and streaked for purity on EMB or similar medium, and suspect colonies picked the next day from this to the TSI agar.

Reactions on TSI agar

In Table II, the reactions of various groups of organisms isolated from faeces or urine on TSI agar after overnight incubation is indicated. In examining for *Shigella* and *Salmonella*, organisms are discarded as indicated.

TABLE II. REACTIONS IN TRIPLE-SUGAR IRON AGAR

Reaction on		H_2S production	Abbreviated recording	Micro-organisms suggested	Indicated procedure for organisms isolated from faeces
slant*	butt**				
Alk	Acid	—	A —	*Shigella, S. typhosa, Proteus*, paracolon, alkalescens-dispar group	Screen and identify as indicated
Alk	Acid	+	A +	*S. typhosa, Proteus*, paracolon, anaerogenic *Salmonella*	Screen and identify as indicated
Alk	Acid and gas	+	AG +	*Salmonella, Proteus*, paracolon (including Arizona)	Screen and identify as indicated (ordinarily many pathogens)
Alk	Acid and gas	—	AG —	Paracolon, *Proteus*, occasionally *Salmonella*	Screen and identify as indicated (ordinarily very few pathogens)
Acid	Acid	—	A/A —	Streptococci, staphylococci, occasionally *S. typhosa*, other gram-negative rods	Screen and identify as indicated if a gram-negative rod; discard others
Alk (spreading growth)	Acid and gas	+ or —	Sp †	*Proteus*	Discard
Acid	Acid and gas	—	—	" Coli-aerogenes "	Examine serologically for entero-pathogenic *E. coli* when indicated; otherwise discard
Alk	Alk	—	—	*Alcaligenes, Mimae, Pseudomonas*	Discard
Purplish	Alk	—	—	*Pseudomonas* species	Discard

* Alk slant indicates lactose and sucrose not fermented; acid slant indicates lactose and/or sucrose fermented.

** Alk butt indicates dextrose not fermented; acid butt indicates dextrose fermented.

† Sp indicates spreader.

Screening

The rapid urease test is the most useful single screening procedure.[6] Growth from all retained TSI slants is inoculated into this medium. With a small loop a generous portion of the growth is transferred into a tube containing 0.2 ml of rapid urease test medium. The results may be read after 30 minutes in a 37°C water-bath. A change in colour to pink or fuchsia indicates hydrolysis of urea and constitutes a positive test. Urease-positive cultures isolated from faeces may be discarded. All urease-negative gas formers (H_2S+ and –) should then be examined by a rapid indole test.[1] A heavy inoculum is indicated and the test requires two hours in the water-bath. It is read after adding Kovacs reagent. Organisms which are indole-positive by this method are not *Salmonella*, and unless there is an interest in the identification and study of paracolon bacilli these may be discarded also. In laboratories handling small numbers of specimens, it is convenient to perform the rapid urease and indole tests simultaneously, reading both after two hours' incubation.

The procedure at this point will vary. Dealing with diagnostic specimens from clinical cases, particularly those ordinarily yielding some *Shigella* or *Salmonella*, one would proceed at once to presumptive serology. However, in other examinations where few *Shigella* or *Salmonella* are identified, the biochemical tests outlined below may be performed before presumptive serology. This latter procedure conserves antisera, which are often in short supply.

Presumptive serology

Organisms selected on the basis of biochemical screening or clinical history are checked with polyvalent and other selected antisera. The following antisera, ordinarily provided from a central laboratory, are required :

Polyvalent *Shigella dysenteriae* (Group A)
Polyvalent *Shigella flexnerii* (Group B)
Polyvalent *Shigella boydii* (Group C)
Shigella sonnei (Group D)
Polyvalent *Salmonella*
Vi

Place a drop of antiserum, diluted as indicated, on a 1-inch × 3-inch (2.5-7.5 cm) glass slide marked in approximately half-inch (1.25 cm) squares. Using a sterile needle, transfer from the TSI slant a portion of the growth and emulsify this in the diluted antiserum. The mixture should be heavily turbid. In practice, the growth from at least five specimens may be suspended in succession in as many drops of serum, and then observed

for agglutination by rocking the slide gently and examining with a bright light and a dark background. A strongly positive reaction indicates the probable group of the organism.

Reporting of presumptive findings

In clinical cases an early report of positive findings at this time is highly useful, and much appreciated by the health officer or clinician. When possible it is desirable to report by telephone, since the presumptive nature of the report warrants emphasis. The final report after further study will ordinarily, though not always, be in agreement.

Identification and Typing

There will be at hand at this stage the organisms identified presumptively as either *Salmonella* or *Shigella* and a variety of unidentified cultures. The former require detailed typing, the latter, cultural confirmation and, in certain instances, typing. The procedures are as follows.

Purification

The replating of cultures to establish purity is always indicated in descriptive bacteriology. However, in diagnostic bacteriology with careful picking of single isolated colonies from the plates and critical inspection of slants, it is necessary only to replate the small percentage of apparently contaminated slants. This effects a substantial saving in time and materials.

Biochemical examinations

The purpose is to conduct the least number of tests for definite identification and to obtain the maximum amount of useful information from a single test. As a minimum, organisms identified serologically as *Shigella* should be tested in mannitol, xylose, and rhamnose. A tube of semi-solid motility medium may be added, although this is not essential. A combined lactose-sucrose broth which is used also for the indole test provides confirmatory information.[8, 12] The reactions shown in Table III are obtained. Inoculation of this series of biochemical tests may be done rapidly, using an inoculating needle, first stabbing the motility medium and, without returning to the TSI, dipping in rapid succession into the broth in the remaining tubes.

Further biochemical tests are not generally regarded as essential in the examination of *Salmonella* which have been identified serologically. Confusing cross-reactions with some paracolon types, such as Arizona, must be acknowledged as a possibility, however.

TABLE III. BIOCHEMICAL TESTS OF MAJOR VALUE IN IDENTIFYING SHIGELLA

Motility*	Indole**	Lactose-sucrose†	Mannitol††	Xylose††	Rhamnose††	Organism suggested
−	V*	−	+	−	−	*S. flexnerii* or *S. boydii*
−	−	−	+	−	+	*S. sonnei*
−	+	−	−	−	+	*S. dysenteriae* type 2 (Ambigua)
−	V§	−	−	−	−	*S. dysenteriae* other than type 2 (Shiga or Sachs)
−	+	−	+	+	+(−)§§	Alkalescens-dispar group
+	−	−	+	+(−)§§	−	*S. typhosa*

* Using semi-solid motility test medium
** Using Sanders' lactose-sucrose medium and Kovac's indole reagent
† The following formula was supplied by A. C. Sanders, US Army Medical Service Graduate School:

Tryptose	20	g
Dibasic sodium phosphate	1	g
Sodium chloride	5	g
Brom-cresol purple (1.6%)	0.5	ml
Distilled water	1000	ml

Autoclave at 15 p.s.i. (1.05 atm.) for 15 minutes. Allow to cool and aseptically add:

Lactose	10	ml (Difco concentrate, 10%)
Sucrose	10	ml (Difco concentrate, 10%)

†† Brom-cresol-purple base with 1% carbohydrate
§ Variable
§§ Occasionally negative

Serologically unidentified organisms must be examined in greater detail; an attempt should be made to identify them by cultural characteristics. Certain tests are particularly useful with non-gas-formers, others with gas-formers. However, in examining unknown enteric organisms a single routine for all is to be recommended, this would include motility, 24-hour urease (Difco), Simmon's citrate, Sanders lactose-sucrose-indole broth, mannitol, xylose, rhamnose, and an agar slant to be used for antigen preparation for subsequent serological tests. Some workers include also IMVIC reactions, and salicin and dulcitol. These tests ordinarily serve to separate the possible pathogens from those which may be discarded as presumed non-pathogens. On the basis of the cultural observations, further diagnostic serological tests may be selected. These studies serve to identify most organisms isolated in enteric bacteriology. Occasionally various other culture procedures are required, but ordinarily this becomes the work of a reference diagnostic laboratory.

Serological typing

Organisms positive in *Shigella* group antisera with confirmatory cultural characteristics are identified as to type, using absorbed *Shigella* typing

sera. The worker should check first for organisms in the group which, by previous experience, are encountered most commonly, and proceed to the less commonly encountered types. Strong agglutination with one type and no reaction in any closely related type satisfactorily classifies an organism. When the living suspension of a micro-organism having the characteristics of *Shigella* is not agglutinated in known sera, a suspension should be heated to 100°C for 30 minutes and retested. This is particularly important in identifying members of the alkalescens-dispar group.

The typing of *Salmonella* in accordance with the Kauffman-White schema should proceed as outlined in the manual of Edwards & Ewing.[3] For clinical purposes this detailed identification is not essential, but for epidemiological purposes all *Salmonella* should be typed.

Reporting of findings

Of major importance here is the decision as to laboratory observations which have clinical or epidemiological significance. The reporting of organisms of the alkalescens-dispar group (not now considered *Shigellae*) is misleading rather than helpful. It is recommended that, except possibly in infants, these organisms when found should not be reported. It is to be remembered, also, that the physician receiving laboratory findings is not familiar with changes in terminology in the identification of *Shigella* and *Salmonella*. It is therefore desirable to include in the report as a synonym the older designation employed for organisms.

Certain tests rarely needed, and those requiring test reagents which are difficult to maintain (e.g., 'phage typing of *S. typhosa*, *Salmonella* typing, and the identification of problem organisms), are available in reference laboratories. In the case of *S. typhosa*, colony fishings which yield significant reactions should be subcultured immediately upon egg medium, and the subcultures, after overnight incubation, should be stored in the refrigerator until the organism has been identified. If it proves to be *S. typhosa*, then one or more egg medium cultures should be sent for typing without delay. For each culture the following information is of importance to public health authorities for subsequent epidemiological reports : name of case or carrier, source (faeces, blood, bile, gall-bladder), related previous 'phage typings, duration of carrier state if known, and epidemiological relationships among cultures in relation to outbreak.

Preparation or Procurement of Antisera

The preparation of the wide variety of diagnostic antisera required in enteric bacteriology is a time-consuming and difficult task for which few laboratories are equipped. The methods recommended have been

outlined by Edwards & Ewing.[3] Good quality diagnostic antisera are not always available commercially.*

Serological Diagnosis

The routine serological examination of blood serum for agglutinins against *S. typhosa*, *S. paratyphi A*, and *S. paratyphi B*, may be employed. There are other *Salmonella* which produce disease, but the multiplicity of antigenic types makes it impracticable to test for agglutinins against all of them. Under special circumstances, as in an epidemic, it might be practicable to test for agglutinins against the etiological organism isolated in the particular outbreak. As with most agglutination reactions using patients' sera, the results should serve only as a diagnostic suggestion. The interpretation of agglutinin titres obtained by testing a single specimen of serum is difficult; evidence of a rising titre is of much greater significance. A current infection is more convincingly indicated if a significant (fourfold) rise against a specific antigen has been demonstrated. This procedure requires the examination of at least two serum specimens taken at least 7-10 days apart. Tests should be carried out using both H and O antigens for typhoid, and, if performed also, with H and O antigen for paratyphoid B. In the diagnosis of typhoid fever, O agglutinins are of more significance, since some cases fail to develop H agglutinins, and O agglutinins disappear more rapidly than H agglutinins after TAB vaccination.

(1) *Preparation of specimen.* Blood drawn aseptically is allowed to clot at room temperature. The serum is separated from the cells by centrifugation and is refrigerated until used in the test. The clot may be used as material for culture if the specimen is taken during the acute phase of the disease. Chylous or markedly haemolyzed sera should be considered unsatisfactory as they interfere with the reading of agglutination.

(2) *Antigens.* Satisfactory antigens for the rapid slide agglutination tests are available commercially. These antigens are usually prepared from killed suspensions of smooth cultures by the methods of Welch[13] or Diamond.[2]

(3) *Control sera.* Human or rabbit antisera of known agglutinin titres should be used as controls. Each new lot of purchased antigen should be tested for sensitivity. If prepared in the laboratory, antigens may be standardized according to the methods of Huddleson[10] or Diamond.[2]

* Such antisera are, however, supplied to specially designated National Salmonella Centres and National Shigella Centres by (*a*) the International Salmonella and Escherichia Centre, Copenhagen, Denmark; (*b*) the International Shigella Center, Atlanta, U.S.A.; and (*c*) the International Shigella Centre, London, England. Details of these services will be available in the report of a World Health Organization Consultant Group on the work of international centres for standards on enteric bacteria, to be published shortly by WHO.—ED.

Test procedure

Equipment includes 3-inch×2-inch (7.6×5 cm) microscopic slides upon which paraffin wax rings about 1 cm in diameter have been mounted, slide holders which will accommodate three of these slides, and a mechanical rotator that can be set at approximately 175 revolutions per minute (r.p.m.). (This equipment is commonly used in the microflocculation serological tests for syphilis.) The technique used in performing concurrently the routine rapid slide agglutination tests is as follows: 0.04 ml of serum no. 1 is placed in the wax ring depression on each of four slides. Serum no. 2 is placed in depression no. 2, etc., until each slide contains 0.04 ml of serum of 10 different specimens. To each specimen on slide no. 1, there is added 0.03 ml of typhoid O antigen, similarly typhoid H antigen is added to specimens on slide no. 2. The same procedure may be used also for paratyphoid B. The slides are placed on the mechanical rotator and rotated for 4 minutes. They are then read over a lighted viewing box. By using 0.04 ml of serum with 0.03 ml of antigen, the test is comparable to a 1/40 dilution by the tube method. Any specimen giving a 2+ or stronger reaction is then checked for possible higher titre. This is done by using smaller amounts of serum with 0.03 ml of antigen, as described by Huddleson.[10] For example, 0.02 ml of serum is equivalent to a 1/80 dilution, 0.01 ml to a 1/160 dilution and 0.005 ml of serum to a 1/320 dilution. Higher dilutions are obtained by diluting the original serum with negative serum and repeating the test as above.

A tube test, using appropriate antigen, is an alternative elective procedure.

Test for Vi agglutinins

The isolation of *S. typhosa* from the stool of a typhoid carrier is admittedly the most convincing evidence of the carrier state. However, this technique is an expensive, laborious, and often uncertain procedure. Coupled with these difficulties is the fact that the chronic typhoid carrier often excretes the bacilli intermittently. The serological examination of serum specimens for Vi agglutinins appears to offer a more practicable method for screening-out possible typhoid carriers. This test was devised by Felix[4] and is performed routinely in England and Canada. Recently the preparation of a more stable antigen has been described by Saint-Martin & Desranleau employing the Bhatnager strain Vi I of *S. typhosa*.[11] The antigen is an alcohol-treated suspension of the organism and is suspended in 50% glycerol solution in 0.1% NaCl at a pH of 7.0. The test procedure employs the rapid technique (0.03 ml serum plus 0.03 ml antigen) and the results are read under a stereoscopic microscope at a magnification of approximately 72 diameters. All sera positive at dilution

1/2 are diluted 1/5, 1/10, 1/20, etc., and retested. Titres of 1/2 are considered weakly positive, 1/5 or 1/10 positive, and 1/20 or higher strongly positive. Persons who show weakly positive or stronger agglutinations should have repeated stool examinations for *S. typhosa* before the possibility of the carrier state is ruled out. Certain "false positives" may indeed reflect a hidden chronic infection from which the bacilli are rarely excreted.

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ANNEX 12

BACTERIOLOGICAL EXAMINATION OF MANUFACTURED MEAT PRODUCTS *

General Principles

From a bacteriological viewpoint, manufactured meat products can be divided into four groups:

1. *Raw non-salted products*, where no heat treatment or curing chemicals (salt, nitrate, nitrite) have been applied. Such products will contain the natural bacterial flora of fresh raw meat, and are subject to the microbiological processes that may develop naturally in meat free from chemical inhibitors.

2. *Raw salted products*, where no heat treatment has been applied, but where curing chemicals have been added in varying concentrations. Owing to the selective effect of salt, nitrate, and nitrite, the bacterial flora of these products will consist primarily of salt-tolerant organisms, while microbiological processes are restricted, owing to the effect of chemical inhibitors.

3. *Cooked or baked meat products, salted or non-salted.* These are products that have been submitted to some kind of low-temperature heat treatment. The bacterial flora is dominated by spore-bearing species (*Bacillus*, *Clostridium*) and certain non-spore-bearing but thermo-resistant species (*Enterococcus*, *Streptococcus viridans*, and *Thermobacterium*). If the products are heated as well as salted, the curing chemicals will inhibit the activities of the surviving micro-organisms.

4. *Sterilized meat products.* These are products that have been submitted to a high-temperature heat treatment (autoclave). Consequently, in theory they are sterile, provided that they are packed in non-leaking, hermetic containers.

These are the four main groups, and each group naturally presents its own characteristic microbiological pattern. The choice of methods for bacteriological analysis will vary according to the type of product, as will the interpretation of findings.

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Generally speaking, the purpose of bacteriological examination of food products is to control one or more of the following characteristics: state of freshness, keeping quality, hygienic standards of production, and content of pathogenic organisms. In order to achieve this purpose the bacteriologist must perform a qualitative as well as a quantitative analysis of the bacterial flora of the food. His methods must include the application of selective and indicative media which will allow him as far as possible to distinguish the important groups of organisms, and as the practical interpretation of findings of micro-organisms very often depends upon a quantitative evaluation, it is essential that he adopts quantitative or semi-quantitative cultural techniques.

Raw, Non-salted, or Salted Meat Products

Examination of raw forcemeat, raw salted or non-salted sausages (pork sausage, salami), and similar products may include: (*a*) direct microscopic examination, (*b*) plating in ordinary agar for aerobic count and in blood-agar for haemolytic and potential food-poisoning organisms, (*c*) examination for *Salmonella*, and (*d*) examination for *Clostridium*.

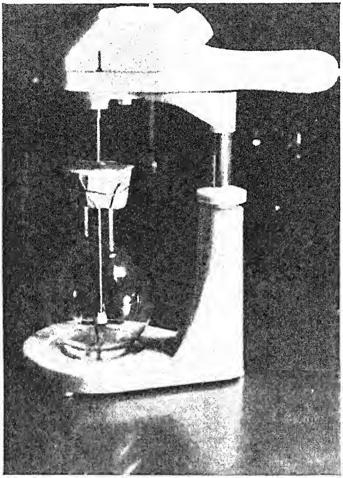
Sampling and preparation of sample

Products not consisting of minced meat must first be ground twice by means of a sterilized meat-grinder with a 2-mm disc, and a sample of 20 g be transferred to a sterile round flask with 180 ml of sterile saline solution. Sterile paper sheets should be used for weighing. The flask should have a wide opening, and homogenization of the sample is performed by means of a high-speed electric stirring machine, the shaft of which is equipped with a four-bladed knife fitted to rotate within the flask (see Fig. 1). From products consisting of minced meat, such as sausages and forcemeat, a 20-g sample is submitted to homogenization directly with 180 ml of sterile saline solution. Care should be taken to secure a representative sample covering a cross-section of external as well as internal layers according to circumstances.

Direct microscopic examination

While homogenization of the sample for plating is taking place, a gram-stained smear taken from the original material should be examined. This simple examination should never be omitted. First, it gives a good estimate of the magnitude of the bacterial content of the material, suitable for determining the appropriate dilutions for plating. For a rough estimate

FIG. 1. ELECTRIC STIRRER FOR HOMOGENIZATION OF SAMPLE



one bacterium per field (oil-immersion) can be taken to indicate about 500 000 per gram of the original material. If each microscopic field shows large numbers of bacteria, very high counts can safely be expected, provided the examination is dealing with unheated material. In heated, frozen, or dried products some of the bacteria, although stainable, may no longer be viable ; in this case high microscopic counts coinciding with a low colony count will indicate that extensive microbial activity has taken place in the product before the bactericidal treatment. Secondly, the direct microscopic examination can very often yield valuable information as to the composition of the bacterial flora. It often shows which type of organism is the most prevalent, or whether some unusual organisms are present—findings which might cause modification or change in the usual routine culture methods. With a preponderance of yeasts, it may be useful to add special media for their cultivation, and as the routine methods include only aerobic cultivation, the microscopic demonstration of a preponderance of gram-positive rods resembling clostridia must, of course, induce the supplementary application of anaerobic methods of cultivation ; otherwise a grave misinterpretation of the case is unavoidable.

Plating in ordinary agar and in blood-agar

From the homogenized 1/10 suspension, serial dilutions in tubes of 9 ml sterile saline solution should be prepared. Two parallel series of Petri dishes are inoculated with 1-ml portions of the appropriate dilutions and poured with ordinary meat-infusion-peptone agar and 5% blood-agar respectively. After solidification the agar plates are incubated at 30°C for 3 days, and the blood-agar plates at 37°C for one day.

After incubation the agar plates are counted by means of a colony counter, and the result is reported as *total aerobic count per gram*. The blood-agar plates are examined for haemolytic colonies (haemolytic streptococci, staphylococci, and *Bacillus cereus*), and non-haemolytic micrococci and streptococci, producing slight haemolysis or greenish discoloration of the blood-cells (enterococci and streptococci of the viridans group). The counts are reported for each individual group of organism, with special attention to potential food-poisoning species, such as haemolytic staphylococci, *B. cereus*, and enterococci. The objective of the examination should be a quantitative and qualitative analysis of the bacterial flora, supplying as much information as possible on its composition. Blood-agar plates are especially useful for this purpose, as many important groups of micro-organisms are easily recognizable from their cultural characteristics when grown on this medium. Apart from the above-mentioned groups and species, the bacillus group and the gram-negative rods (coliforms, *Proteus*, *Pseudomonas*, and others) can usually also be recognized from cultural characteristics of colonies, either in ordinary agar or in blood-agar. Microscopic examination of wet preparations in the phase-contrast microscope, or morphological studies of nigrosin or gram-stained film preparations are very helpful in the tentative diagnosis of colonies. If complete identification is desired, the worker must resort to the recognized standard methods of pure culture study. For instance, results may be reported as follows: total aerobic count: 2 500 000 per gram; blood agar count: 500 000 streptococci (enterococcus-viridans group) plus 200 *B. cereus* per gram. The predominant groups of organisms are gram-negative rods, non-haemolytic micrococci, and bacilli.

Examination for salmonella

For this purpose the classical enrichment techniques by means of tetrathionate broth and subsequent streaking on differential plates, as used in stool examinations, may be applied. A modification of the classical procedure, especially for the examination of meat products, has been worked out by a team of workers (Galton, Lowey Hardy, and others) at the Communicable Disease Center, Atlanta, Georgia, USA:

30 g of minced material is transferred to an Erlenmeyer flask; 6 ml of

a 10% solution of "D-tergitol" (a wetting agent) plus 100 ml of tetrathionate broth are added. After shaking until the material has been well suspended into the fluid, the flasks are incubated at 37°C for 18-20 hours. The enrichment cultures are streaked on phenol-red brilliant-green lactose saccharose agar plates containing 8-16 mg of sulfadiazine per 100 ml of medium. Incubation is at 37°C for one day. Suspect colonies are transferred to triple sugar iron-agar slants and identified by serological and biochemical tests.

When dealing with material, for instance dried foods, which can be expected to harbour only very few viable salmonella bacteria, this laboratory has found it preferable to cultivate the material first in plain broth instead of using inhibitory selective media directly. After 16-18 hours of incubation, the broth culture is centrifuged, and after the supernatant fluid has been discarded the tube is filled with tetrathionate broth and re-incubated for another 18-20 hours before plating. This principle has been introduced by Müller [8] in the examination of meat- and bone-meal. Instead of cultivating the broth culture sediment in enrichment media, Müller inoculated it into mice, as he was interested in demonstrating *Salmonella* and other pathogenic micro-organisms.

Examination for clostridia

When direct microscopic examination or other circumstantial evidence indicates the presence of clostridia in significant numbers, a special examination for clostridia may be warranted.

This examination should not only demonstrate the presence of clostridia, but also permit of a quantitative estimate of their numbers. There are, however, certain difficulties in devising a suitable technique for counting anaerobic bacteria. These difficulties arise from the fact that ordinary methods of anaerobic cultivation cannot be regarded as specific for anaerobes. Even strict anaerobic conditions will not prevent growth of facultative anaerobic species together with the anaerobes. Thus, if the material contains a mixed population, as is usually the case with natural materials, primary cultures will always show a mixture of anaerobic and non-anaerobic organisms; heating may destroy all vegetative cells and leave only spores, but, in addition to clostridia, aerobic bacillus species are also spore-forming. Moreover, as shown by Lind,[4] in many natural materials the content of vegetative cells of clostridia is much higher than is the number of spore-forms, so that to count spores only in heated inoculum may produce highly misleading results. Since there are no specific selective methods available for the cultivation of anaerobes, it seems necessary to adopt methods which will support growth of anaerobes together with other bacteria, and to judge the presence of anaerobes from certain characteristic

reactions of the positive cultures. The Crossley * medium meets this principle better than any other medium known to the author. The changes produced by clostridia when grown in bromocresol-purple milk are so characteristic that in most cases it is possible to decide whether anaerobes are present in the culture or not, and moreover the different types of reaction allow proteolytic and saccharolytic species of anaerobes to be distinguished. On the other hand, the Crossley medium suffers from the obvious disadvantage that acid-producing streptococci may outgrow small numbers of clostridia, and by turning the milk medium sour may prevent the multiplication of clostridia. For this reason it is advisable to apply at the same time strongly buffered von Hibler's brain-broth medium. This medium offers excellent anaerobic conditions of growth, but growth of clostridia does not produce easily recognizable typical reactions, except for the blackening and putrid odour produced by certain proteolytic, hydrogen-sulfide-positive species. Microscopic examination of wet preparations by means of the phase-contrast microscope may help to determine the presence of clostridia in suspect cultures.

Technique : Two series of tubes, one with Crossley's milk bromothymol-blue cresol-purple fishmeat medium and one with von Hibler's brain broth medium, are inoculated with 1-ml portions of the serial dilutions from $10^{\div 1}$ to $10^{\div 5}$ or higher which are used for plating in ordinary agar and blood-agar. The Crossley tubes should be freed from dissolved oxygen by boiling and re-cooling immediately before use. The tubes are incubated at 37°C for at least 72 hours.

Reading of Crossley tubes : The changes brought about by bacterial growth (fermentation of lactose, gas production, coagulation and peptonization of the milk) will indicate certain essential biochemical characteristics of the bacteria, allowing a tentative diagnosis. Confirmative tests would require plating from positive tubes and further examination of pure cultures.

Anaerobic species reactions :

Type 1. Neutral or alkaline reaction (purple colour) ; gas ; soft coagulum followed by rapid dissolution of the casein, resulting in a rather brownish fluid ; dark sediment ; putrid odour : indicates, for example, *Cl. putrificum*, *Cl. sporogenes*, *Cl. flabelliferum*, *Cl. oedematiens*, *Cl. histolyticum*.

Type 2. Very soft coagulum after 2-3 days ; no change of pH ; weak formation of gas ; later complete peptonization with alkaline

* Devised originally by Crossley [1] and modified in 1948 by H. Riemann, Danish Ministry of Fisheries Research Laboratory.

reaction; no putrid odour: indicates, for example, *Cl. centrosporogenes.*

Type 3. Slightly acid (pale yellow colour); soft coagulum; formation of whey; weak formation of gas: indicates, for example, *Cl. sphenoides.*

Type 4. Acid (bright yellow colour); hard curd; gas; sometimes the indicator is reduced: indicates, for example, *Cl. butyricum.*

Type 5. Acid and gas (stormy fermentation): indicates, for example, *Cl. perfringens.* Less gas and cloudy whey indicates, for example, *Cl. tertium.*

Aerobic species reactions:

Type 6. Alkaline reaction; incomplete peptonization beginning from the surface and proceeding downwards; no gas; no putrid odour, and no blackening: indicates, for example, *B. subtilis, B. vulgaris.*

Type 7. Acid coagulation; no gas; sometimes only acid without coagulation; peptonization may occur: indicates, for example, *B. cereus, B. coagulans, B. silvaticus*; lactic acid bacteria (streptococci, lactobacilli).

In reading the type of reaction and in noting the ultimate dilution which has produced anaerobic growth, qualitative as well as semi-quantitative information on the anaerobic flora of the specimen may be extracted.

Correlation of bacterial counts to hygienic standards of production

Raw meat products very often show remarkably high bacterial counts. This, however, does not necessarily indicate low hygienic standards of production, as the carcasses from which the manufactured product originates have very often been kept for some time in cold storage before being used for manufacture. During storage, multiplication of the contaminating flora takes place, and when the meat of such carcasses with a high surface count, although still organoleptically fresh, is cut and minced, the sausage-meat or forcemeat naturally becomes very rich in bacteria. The use of high-count raw materials must of course result in high-count finished products when the process of manufacture does not include any step, such as heating, which will destroy the micro-organisms. The handling of high-count raw materials, moreover, will very quickly build up a heavy contamination of table-tops, vats, machines, and utensils in the factory, even if premises and equipment at the outset of work were in a perfectly clean and sanitary condition. The fact that the meat industry in ordinary practice is dealing with high-count raw material does not mean that sanitation and sanitary practices in sausage factories and meat plants are of no use. On the contrary, the exposure to heavy in-plant contamination necessitates

strict sanitary measures. The serious contamination of raw sausage-meat which may result when unclean machines (mincers, chopping machines etc.) are used has been clearly demonstrated by Vollan [12] in bacteriological investigations of sausage-making under experimental conditions. In practice, however, it is difficult to apply bacteriological standards to raw meat products and to judge the hygienic standards of production from bacterial counts, because it is impossible to conclude whether high counts are due to the use of high-count raw materials, contamination from unclean utensils, or both.

Correlation of bacterial counts to state of freshness and keeping quality

Although the results of bacteriological examination of raw meat products are generally not very useful in judging hygienic standards of production, they may offer valuable information as regards state of freshness and keeping quality.

In raw meat products a correlation between bacterial count, state of freshness, and keeping quality can be expected to exist as long as there are no chemical inhibitors in the product. In salted or otherwise chemically preserved meat products, the salt and other curing chemicals will interfere with the microbiological processes; the ratio of salt (and other curing chemicals) to water content is the critical factor which determines the course of microbiological activity. The ratio of salt to water appears from a determination of the percentage of salt in the water phase

$$\frac{(\text{percentage of salt} \times 100)}{\text{percentage of water}}.$$

If the ratio is high, i.e., 20% or more, there will be little possibility of bacterial multiplication or microbiological enzymatic activity. The bacteria, although viable, are inactive and numbers diminish during storage. In this case, therefore, even high bacterial counts bear no relation to the state of freshness and keeping quality of the product. An example of this kind of product is raw salami sausage of the strongly salted type.

Chemical analysis of salted meat products : $\frac{salt\ (\%) \times 100}{water\ (\%)} > 20.$

	% water	*salt*	*salt/water ratio*	*fat*
Salami I	13.8	6.54	47.4	64.07
Salami II	33.7	9.23	27.4	
Salami III	38.0	8.60	22.6	

If the salt/water ratio is between 10 and 20, certain highly salt-tolerant micro-organisms may develop. Usually such species, however, are biochemically inactive towards proteins and other constituents of the meat, or the enzymatic activities, especially proteolytic enzymes, are inhibited by

the high concentrations of salt and other curing chemicals, to the effect that bacterial counts bear little or no relation to the state of freshness and keeping quality of the product. An example of a product of this type is given below.

Chemical analysis of salted meat products : $\dfrac{salt\ (\%) \times 100}{water\ (\%)} \begin{matrix} > 10 \\ < 20 \end{matrix}$

	% water	salt	salt/water ratio	plate count
Salami I	28.8	4.2	14.4	40 million/g
Salami II	38.0	6.7	17.6	7.4 million/g

In lightly cured products having a salt/water percentage below 10, more species of micro-organisms may develop, including micrococci, enterococci, *Achromobacter*, *Proteus*, and *Pseudomonas*; below 5-6, clostridia may also be found. At the same time enzymatic activity is less inhibited, and the course and rate of reaction of the decomposition process approach the standards for non-salted meat products. Consequently bacterial counts may be of considerable use in judging the state of freshness and the keeping quality of lightly cured meat products. Examples of this type of product are raw salted bacon and lightly cured raw salami.

Chemical analysis of salted meat products : $\dfrac{salt\ (\%)}{water\ (\%)} < 10.$

	% water	salt	salt/water ratio
Sausage	59.5	2.54	4.3
Bacon	71.3	4.2	5.9

The correlation of bacterial counts to the state of freshness and keeping quality in raw non-salted meat products is seen from the examples given below.

Bacterial counts, pH, tests for NH_3 and H_2S

	Raw pork sausage kept at 10°C			
	freshly prepared	after 1 day	after 2 days	after 3 days
Total count	15.2 million/g	360 million/g	461 million/g	720 million/g
pH	6.0	5.9	5.5	5.35
NH_3	0	(+)	+	+
H_2S	0	+	+	+
Organoleptic examination	normal	not fresh	spoiled	spoiled

	Raw pork sausage kept at 17°C	
	freshly prepared	after 1 day
Total count	15.2 million/g	2800 million/g
pH	6.0	5.50
NH_3	0	+
H_2S	0	+
Organoleptic examination	normal	spoiled

	Raw pork sausage kept at 2°C				
	freshly prepared	*after 1 day*	*after 2 days*	*after 3 days*	*after 4 days*
Total count	15.2 million/g	5.5	52	72	136
pH	6.0	6.0	6.0	6.0	6.15
NH_3	0	0	0	+	+
H_2S	0	+	+	+	+
Organoleptic examination	normal	normal	normal?	not fresh	not fresh

It may be tentatively stated that bacterial counts between 50 and 100 million per gram coincide with the onset of organoleptic symptoms of spoilage, when dealing with raw meat products which are free from chemical inhibitors and contain enough water to support unrestricted propagation of micro-organisms, similar to the logarithmic phase of growth of a culture. From the example given above, the different course of changes of pH reflects the difference in biochemical activities of the frigophilic and the mesophilic bacteria respectively. The frigophilic flora which develops at +2°C does not produce acid, while the mesophilic flora which develops at +10°C and +17°C obviously ferments the carbohydrates of the added milk and flour.

Low-Temperature Heat-Treated (Cooked or Baked) Meat Products

This category includes all kinds of non-sterilized (pasteurized) meat products. The surviving microflora is composed of thermo-resistant non-sporogenic or sporogenic gram-positive organisms, while the heat-sensitive gram-negative organisms, such as the *Escherichia-Aerobacter* group, are absent, provided the product has not been exposed to recontamination after the heat treatment. It appears that the bacteriological status of this type of meat product is very similar to that of pasteurized milk. Consequently the principles of bacteriological examination are very much related to those applied in the control of pasteurized milk. Although the time/temperature ranges applied in the processing of meat products of this type admittedly are much higher than those applied in milk-pasteurization, the low rate of penetration of heat in meat means that the actual effect very often does not exceed that of milk-pasteurization. The storage life of these products is, of course, always limited, and depends upon the temperature of storage. Other factors influencing the storage life are curing (salted or non-salted products, percentage of salt in water), and the method of packing (hermetic or open).

In the following section a description is given of the principles which are followed in Denmark in the examination of two different types of low-temperature heat-treated meat products. One is a group of perishable made-up meats, such as non-hermetically packed liver paste, brawn, meat loaves,

cooked luncheon sausage, Vienna sausages, etc. Another group is low-temperature heat-treated cured, canned pork products (hams, shoulders, Wiltshire-style bacon, etc.).

Non-hermetically packed liver paste, brawn, meat loaves, cooked luncheon sausage, Vienna sausages, etc.

Madelung [2] suggested a technique of examination which will answer the following questions:

(1) Are the products at the moment of sale or after 2 days' storage at inadequate storage temperatures (18°C) in a condition which involves a risk of producing food poisoning?

(2) Are the bacteriological standards of the products at the moment of sale in conformity with the standards which with reason can be expected from heat-treated products?

(3) Does the keeping quality of the products permit of a reasonable storage life at suitable storage temperatures?

Technique of examination: To cover the aims mentioned above, Madelung introduced the principle of a double bacteriological examination. He divides the samples into two parts; one is examined at once, the other after pre-incubation at 18°C for 2 days. The examination of the fresh sample involves only plating in ordinary agar for a total aerobic count, while the examination of the pre-incubated sample includes plating in blood-agar for counting potential food-poisoning organisms (haemolytic staphylococci, *B. cereus*, enterococci), coliform count, and examination for clostridia. In special cases examination for the presence of *Salmonella* may be included.

Sampling and preparation of sample

A 40-g sample is divided into two equal parts. Sterile paper sheets are used for weighing. One sample is examined immediately (plate count), while the other is placed in a sterile Petri dish and left in an incubator at 18°C for 2 days and afterwards examined (plating in blood-agar, coliform count, and examination for clostridia). Homogenization with 180 ml of sterile saline solution is performed as described on page 421.

Direct microscopic examination

This is performed as described on page 421.

Plating in ordinary agar from the fresh sample and in blood-agar from the pre-incubated sample

This is performed as described on page 423. The appropriate dilution for the total aerobic count in the fresh sample is $10^{\div 3}$. The agar plates are

incubated at 30°C for 2 days. The appropriate dilutions for plating in blood-agar from the pre-incubated sample are $10^{\div 5}$ and $10^{\div 6}$. The blood-agar plates are incubated at 37°C for one day.

Coliform count in the pre-incubated sample

Petri dishes should be inoculated with 1-ml portions of the diluted homogenized material and poured with violet-red-bile agar ; an appropriate dilution is $10^{\div 2}$. Alternatively, 0.1 ml of the $10^{\div 1}$ dilution may be streaked on the surface of an eosin-methylene-blue agar plate. Incubate the cultures at 37°C for 20 hours.

Examination for clostridia in the pre-incubated sample

This is performed as described on page 424. Appropriate dilutions are $10^{\div 1}$ and $10^{\div 2}$.

Examination for salmonella

This may be performed as described on page 423.

Interpretation of results : Total aerobic counts in fresh sample should not exceed 100 000. The pre-incubated sample should be free from haemolytic staphylococci, *B. cereus*, and enterococci in $10^{\div 5}$ g, and coliforms or clostridia should not be demonstrable in $10^{\div 2}$ g.

Low-temperature heat-treated cured canned meat products (hams, shoulders, Wiltshire-style bacon, etc.)

Although low-temperature heat-treated cured and canned meat products are non-sterile, sound products normally contain only small to moderate numbers of viable organisms. The bacterial flora of canned hams and similar products may be listed as follows.

Clostridia : Usually absent in sound products or demonstrable only in small numbers. Often present in cans showing swelling. Two main groups are found, butyric acid group (e.g., *Cl. perfringens*) and the putrificus group (e.g., *Cl. sporogenes*). The butyric acid group produces a sour non-fresh smell of butyric acid or other volatile fatty acids, but no hydrogen sulfide, while the putrificus group produces a foul smell of hydrogen sulfide and sometimes liquefaction of the contents.

Bacillus : Often present in small to moderate numbers in sound products. According to reactions in Crossley medium, two types may be distinguished : one produces an acid coagulation (reaction-type 6), while the other produces an alkaline reaction and slow and incomplete peptonization, beginning from the surface (reaction-type 7). Spoilage may be

associated with the presence of large numbers of bacillus species. Such cans often show light swelling, and cultures in deep-glucose agar tubes may show small bubbles of gas, apparently produced by nitrate-reducing bacilli from the inoculum of cured meat. *B. cereus* (potential food-poisoning organisms) should not be found in significant numbers.

Streptococci of the enterococcus-viridans group and lactobacilli: These thermo-resistant lactic acid bacteria are usually absent or very scarce in sound products. The streptococci have most frequently been identified as belonging to the enterococcus group (growth in 6.5% salt-broth, and growth in litmus milk at +10°C and +45°C). Enterococci and lactobacilli may produce a specific type of spoilage which is characterized by the development of a specific acid smell and taste reminiscent of vinegar or sour cheese. There is a drop in pH, and the can does not swell. Unsound products of this kind will contain enterococci and/or lactobacilli in large numbers. When lactobacilli are present, " greening " of freshly-cut surfaces may occur. Spoilage due to lactic-acid bacteria seems to be most commonly caused by under-processing.

Micrococci: Non-haemolytic micrococci may occur in small to moderate numbers in sound products. Large numbers may indicate leakage. Haemolytic coagulase-positive staphylococci (potential food-poisoning organisms) should in any case be absent.

Gram-negative rods (coliforms, *Achromobacter*, *Pseudomonas*, etc.) should be absent in sound products. The presence of these non-heat resistant organisms in non-leaking cans indicates gross under-processing. Salmonella organisms should, of course, in any case be absent.

Technique of examination: The routine procedure which is followed by this laboratory in the bacteriological examination of low-temperature heat-treated cured canned meat products includes cultivation in blood-agar plates, glucose broth, deep glucose agar, Niven's medium for lactic acid bacteria, eosin-methylene-blue penicillin-broth for coliforms, Crossley medium and brain-broth for anaerobes.

Sampling and preparation of sample

Whether or not cans which are labelled : " Perishable : keep under refrigeration " should be incubated before bacteriological examination depends upon the purpose of the investigation. If this is a running control of the factory line or a check on the presence or absence of special types of organisms, enrichment by a short period of incubation at suitable temperatures may be advisable. If the purpose is to judge old consignments which have been retained by food control authorities because of some evidence or suspicion of spoilage, the cans should ordinarily be examined directly without pre-incubation.

Aseptic technique for removal of sample from can : Cans to be examined must be thoroughly cleaned and sterilized on the surface before being opened ; they should first be scrubbed with soap, hot water, and a stiff brush to remove visible dirt completely, and then rubbed with alcohol and flamed with a Bunsen burner for about 15 seconds.[10]

To open the can a circular disc of metal about 3.5 cm in diameter is cut out from the lid by means of a sterile specially modified can-opener (see Fig. 2, 3). A sterile metal tube, resembling a cork-borer, is used to bore out a column of the solid material from the centre of the can (see Fig. 4, 5). The tube, which has sharp edges to cut through the meat, measures 250 mm × 15 mm, and is closed with a cotton plug in the upper end. A sterile glass rod is pushed against this plug to press out the sample from the tube (see Fig. 6). Liquid food products may be sampled by means of sterile pipettes made from ordinary glass tubing.

Homogenization of the sample is performed as described earlier (see page 421), using 20 g of material and 180 ml of sterile saline solution.

Inoculation of media

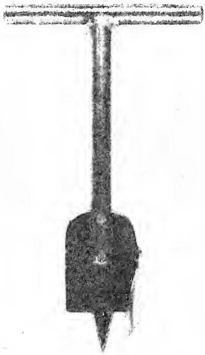
In the selection of media our laboratory follows a programme worked out by H. Riemann. 1-ml portions of the 1/10 dilution are transferred to a Petri dish which is poured with blood-agar, and to a series of tubes with fluid or solid media, as follows : (1) glucose broth ; (2) Niven broth ; (3) eosin-methylene-blue penicillin-broth in Durham tubes ; (4) deep glucose agar ; (5) Crossley milk medium (freshly boiled) ; (6) von Hibler's brain-broth. The rest of the homogenized 1/10 dilution of the material is stored in the icebox. If growth occurs in any of the primary cultures, serial dilutions from the original 1/10 dilution should be made and used for quantitative estimation of the bacterial populations, either by the plate-count method or by the dilution method in fluid-medium tubes.

Cultures are incubated at 37°C for 2 days, anaerobic cultures for 3-4 days or longer.

Reading and interpretation of results

The blood-agar plates will usually give a good indication as to whether aerobic organisms are present in insignificant or in large numbers. Moreover, enterococci, micrococci, bacillus species, and haemolytic staphylococci are easily identified from this medium. If the material contains only small amounts of micro-organisms, the blood-agar plates may be found sterile, while growth occurs in one or more of the fluid-media tubes. Gas in the eosin-methylene-blue penicillin-broth Durham tubes indicates coliforms which should be identified by streaking on eosin-methylene-blue agar

FIG. 2. CAN OPENER * FOR SAMPLING SUSPECT PRODUCTS



* Modified by Jens Sørensen

FIG. 3. CAN OPENER IN USE

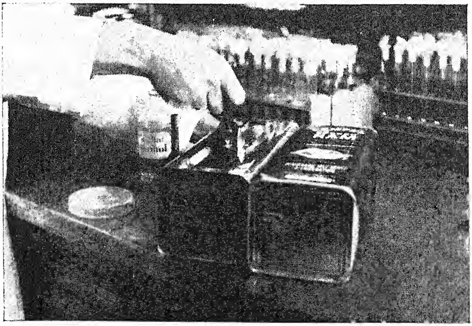


FIG. 4. METAL TUBE FOR REMOVAL OF SAMPLE

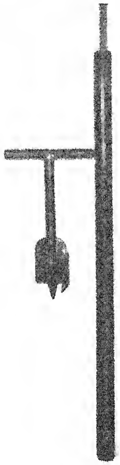


FIG. 5. REMOVAL OF SAMPLE

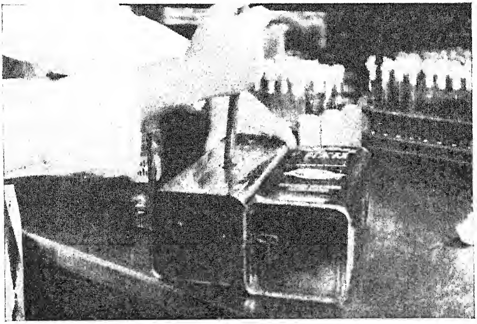
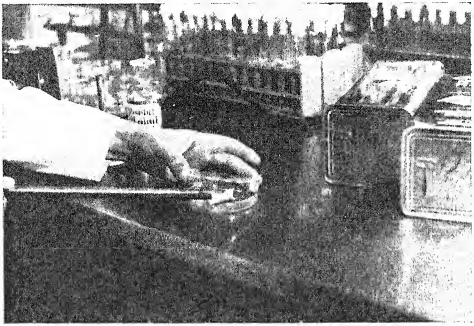


FIG. 6. SAMPLE BEING TRANSFERRED TO STERILE PETRI DISH



plates and by the usual biochemical tests. Lactobacilli usually grow only in Niven broth tubes. The deep-glucose-agar tubes may show formation of gas due to clostridia, coliforms, or special types of bacillus. Crossley and brain-broth cultures are read and examined as described on page 425. Cultures (aerobic as well as anaerobic) which show evidence of growth must be examined microscopically (Gram-stained slides or wet preparations in the phase contrast microscope) in order to analyse the composition of the flora. Whenever necessary the examination of the primary cultures must be supplemented by pure culture study according to the usual techniques of diagnostic bacteriology.

Direct microscopic and organoleptic examination of the contents of the opened cans

After sampling for bacteriological examination, the contents should be taken out of the cans. Gram-stained smears for direct microscopic examination are prepared, and results are recorded for comparison with the results of cultivation methods. The organoleptic examination should establish texture, colour, appearance, smell, and flavour, and the correlation between possible abnormalities and the bacteriological status must be carefully studied. Only through experience collected from such studies can correct interpretation of bacteriological findings be learned.

The organoleptic examination may be supplemented by various biochemical tests (pH, boiling test, test for hydrogen sulfide, determination of volatile acids, etc.).

Sterilized Canned Meat Products

The examination of this type of product is based upon the assumption that the purpose of processing is to produce sterility or a condition close to sterility of the contents of the hermetically-sealed can. The bacteriological examination of apparently normal cans should therefore be performed as a sterility test. The cans should be incubated before the bacteriological examination, and the various media should be inoculated with undiluted samples that are transferred with strict aseptic precautions directly from the can to the test-tubes and Petri dishes. The media used are: glucose broth, deep glucose agar, Crossley milk medium, and blood-agar.

Sampling and preparation of pre-incubated sample

Blown cans should be examined directly, while apparently normal cans are incubated at 37°C for 10 days. In the case of certain cured pork products the period of incubation is 5 days only.

After removal from the incubator the cans are left to cool and then examined for swelling.

Removal of samples from the cans should be performed as described on page 433, while homogenization and dilution of the material should ordinarily be omitted.

Inoculation of media

Portions of approximately one g are transferred to a Petri dish which is poured with blood-agar, and to a series of tubes with fluid or solid media, as follows: (1) glucose broth; (2) deep glucose agar; (3) Crossley milk medium.

Cultures are incubated at 37°C for 2 days, and anaerobic cultures for 3-4 days or longer. If thermophilic organisms are suspected, duplicate tubes with glucose broth, deep glucose agar, and Crossley milk medium may be incubated at 55°C.

Reading and interpretation of results

The use of solid media (blood-agar plates and deep-glucose-agar tubes) in addition to the fluid media facilitates the assessment of the degree to which various organisms are present and eliminates doubt concerning the possibility of contamination of the cultures during their preparation. Accidental contamination may easily produce growth in fluid media, while the

finding of a substantial number of colonies in the solid media makes it safe to conclude that the organisms originate from the sample.

In the majority of cases cultures from normal sound products are found to be sterile. In some cases very scanty growth of aerobic sporebearers (bacillus species) may occur. If the organoleptic findings are negative also, such products may be classified as suitable for consumption. On the other hand, when cultures from sterilized canned meats show definite growth of micro-organisms in significant numbers the product should always be regarded as suspect, no matter which are the species of organisms, and whether organoleptic findings are positive or negative.

If the presence of organisms is due to under-processing, usually only species of heat-resistant sporebearing organisms (clostridia or bacillus) are found. Most often only one species is present in pure culture, but when the product has been grossly under-heated two or more species may be found. If the presence of organisms is due to leakage of the container, a mixed population, including non-heat-resistant non-sporulating species, is usually to be expected.

Direct microscopic and organoleptic examination of the contents of the opened can

After sampling for bacteriological examination, the contents should be taken out of the cans. Gram-stained smears for direct microscopic examination should be prepared and examined, and later an organoleptic examination, eventually supplemented by biochemical tests (pH, boiling test, test for hydrogen sulfide) should establish the texture, colour, appearance, smell, and flavour of the product. Results should be recorded and compared with the results of the bacteriological examination. If direct microscopic examination reveals numerous organisms in the food while cultures are sterile, a pre-process spoilage must be suspected.

The final judgement of suspect consignments should depend upon a careful consideration of all facts, including bacteriological, microscopic, and organoleptic findings, and the overall percentage of swollen cans in the consignment. Re-processing and retesting may be an alternative to condemnation in under-processed products which show no spoilage and no heavy bacterial growth.

Special Media

Niven broth [2]

Tryptone (Difco)	10	g
Yeast extract (Difco)	5	g
Sodium chloride	5	g

Dipotassium phosphate	5	g
Sodium citrate	5	g
Glucose	10	g
Tween 80 (sorbitan mono-oleate)	1	g
Magnesium sulfate	0.8	g
Manganese chloride	0.14	g
Ferrous sulfate	0.04	g
Distilled water ad 1 litre		

Crossley milk medium

Fresh, skinned fillet of cod is cooked in as little water as possible or steamed in a steam boiler. The cooked fishmeat is distributed into test-tubes, approximately 2 g of meat to a tube.

Bromocresol-purple solution : 1 g of bromocresol purple is dissolved in 19 ml of 0.1N NaOH, and distilled water is added to make 100-ml volume.

To one litre of fresh, skimmed milk, 15 ml of normal NaOH, 10 g of peptone, and 10 ml of the bromocresol-purple solution are added. When the peptone has dissolved in the milk, approximately 10 ml of the milk mixture are added to each tube with fishmeat.

Sterilization : 120°C for 20 minutes. Incubation at 37°C for at least 48 hours to check sterility.

After inoculation the tubes are incubated for at least 72 hours at 37°C. If warranted by special circumstances, the period of incubation should be extended before negative results are reported.

von Hibler's brain broth

Minced brain (horse or cattle) mixed with an equal volume of water is boiled in live steam for 30 minutes. The mixture is distributed into sterile tubes which are filled up to a few cm from the plug and sealed with 1 ml of liquid paraffin. Sterilization in the autoclave at 115°C for 30 minutes twice at an interval of 24 hours.

Eosin-methylene-blue penicillin-broth [7]

Peptone	20	g
Dipotassium phosphate	2	g
Lactose	10	g
Eosin, yellowish (Gurr C.J. No. 768)	0.4	g
Methylene blue (Gurr C.J. No. 922)	0.065	g
Distilled water ad 1 litre		

Diagnostic Characteristics of Some Important Groups of Bacteria associated with Meat and Meat Products

In order to facilitate the identification and classification of some important species of bacteria found in meat and meat products, a few basic diagnostic characteristics have been compiled and are reproduced in a schematic form as follows.

Staphylococci

	Staphylococcus pyogenes	*Non-pathogenic staphylococci*
Blood-agar	haemolytic	non-haemolytic
Coagulase	+	0
Mannitol	+	0
Litmus milk	ACR (peptic)	variable

Enterotoxic strains belong to the haemolytic, coagulase-positive *Staphylococcus pyogenes* group. For further differentiation the worker may resort to 'phage typing, and examination of types of growth on crystal-violet agar (Kristensen, cited in Klastrup [3]).

Streptococci

	Pyogenic	*Viridans*	*Enterococci*	*Lactis*
Arginine broth *	NH_3	0	NH_4	0 +
Litmus milk at 45°C	0	+	+	0
Litmus milk at 10°C	0	0	+	+
6.5% salt broth **	0	0	+	0

* Arginine broth is prepared from:

Tryptose	0.5 %
Yeast extract	0.5 %
Glucose	0.05%
Monopotassium phosphate	0.2 %
Arginine	0.3 %
pH = 7	

Nessler's reagent is used for the demonstration of NH_3.

** 6.5% salt broth is prepared from:

Tryptose	1 %
Yeast extract	0.5%
Glucose	0.1%
NaCl	6.5%
pH = 7.0-7.2	

Gram-negative rods

(1) Lactose fermented with gas:

Triple sugar iron agar slants: yellow/yellow gas

	Escherichia	*Aerobacter*
Motility (semi-fluid agar stab)	+	0
Indole	+	0

H_2S	0 (+)	0
Growth at 2°C	0	0 (+)
Litmus milk	acid	acid
Gelatine	0	0 (+)
M. R.	+	0
V. P.	0	+
Urea	0	0

(2) Lactose not fermented, gas from glucose:

	Triple sugar iron agar slants: red/yellow gas, blackening		
	Salmonella	*Arizona type*	*Ballerup-Bethesda type*
Motility	+	+	+
Indole	0	0	0
H_2S	variable	+	+
Growth at 2°C	0	0	0
Litmus milk	0	0	0
Gelatine	0	+	0
M. R.	+	+	+
V. P.	0	0	0
Mannitol	+	+	+
Urea	0	0	0
		Late lactose fermenter	

	Triple sugar iron agar slants			
	yellow/yellow gas, blackening	*red or yellow/yellow gas, blackening*		*red/yellow gas blackening*
	Proteus vulgaris	*Proteus mirabilis*	*Proteus rettgeri*	*Proteus morgani*
Motility	+	+	+	+
Indole	+	0	+	+
H_2S	+	+	0	+
Growth at 2°C	(+)	(+)	(+)	(+)
Litmus milk	peptic	peptic	alkaline	alkaline
Gelatine	+	+	0	0
M. R.	+	+	+	+
V. P.	0	0	0	0
Mannitol	0	0	+	0
Urea	+	+	+	+

(3) Lactose not fermented, no gas:

	Triple sugar iron agar slants		
	red/red or yellow	*red/red*	*red/red*
	Achromobacter	*Pseudomonas*	*Alcaligenes*
Motility	+ (0)	+	variable
Indole	0	0	0
H_2S	variable	0	variable
Growth at 2°C	+	+	+
Litmus milk	0	peptic	alkaline
Gelatine	variable	+	variable
M. R.	0	0	0
Urea			0

B. cereus

St. Hauge (cited in *Nord. VetMed.*[9]) has recommended the following technique of identification:

Blood-agar	a wide distinct zone of haemolysis
Lecithinase	+
V. P.	+
Reduction of nitrate	+
Crossley milk medium	peptic

Surface colonies on blood-agar are circular, large, flat, and finely granular, while deep colonies have a cotton-like fluffy appearance. The colonies are surrounded by a large, clear, and very sharp-edged zone of haemolysis. The *lecithinase reaction* is performed in the following way:[5] One egg yolk is mixed with 200 ml of saline and filtered through asbestos wool and Seitz filter discs. To 0.5 ml of egg-yolk solution is added 0.2 ml of a broth culture. Within an hour at room temperature an opacity develops, due to the formation of droplets of neutral fats. Later the fat accumulates as a fatty layer on top of the fluid.

For *Voges-Proskauer test* the following technique must be used:[11]

Voges-Proskauer medium

Proteose peptone	7 g
Glucose	5 g
NaCl.	5 g
Distilled water	1000 ml

The cultures should be incubated at 30°-32°C and examined after 2, 4, 6, and 10 days for the presence of acetyl-methyl carbinol. Equal parts of the culture fluid and 40% sodium hydroxide are mixed with a few milligrams of creatine. The tube is left for one hour in a horizontal position. Red colour indicates acetyl-methyl carbinol.

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ANNEX 13

TEMPERATURE CONTROL AND SALT TREATMENT OF MEAT CONTAINING TRICHINAE OR CYSTICERCI

A. Trichinosis

Heating

The regulations of the United States Government [8] stipulate:

" All parts of the pork muscle tissue shall be heated to a temperature not lower than 137°F [58.3°C], and the method used shall be one known to insure such a result. On account of differences in methods of heating and in weights of products undergoing treatment it is impracticable to specify details of procedures for all cases.

" Procedures which insure the proper heating of all parts of the product shall be adopted. It is important that each piece of sausage, each ham, and other product treated by heating in water be kept entirely submerged throughout the heating period; and that the largest pieces in a lot, the innermost links of bunched sausage or other massed articles, and pieces placed in the coolest part of a heating cabinet or compartment or vat, be included in the temperature tests."

Refrigeration

Wright [9] recently reviewed the present position in the USA with respect to refrigeration of meat and meat products for trichinosis. He states:

" There have been no changes in the past year in requirements of the federal meat inspection regulations concerning the freezing of pork or pork products customarily eaten without cooking by the consumer. For pieces not exceeding 6 in. (15.2 cm) in thickness or stored in crates not exceeding 6 in. in depth, the holding time prescribed is 20 days at 5°F [–15°C], 10 days at –10°F [–23°C], or 6 days at –20°F [–29°C]. For products in layers or containers exceeding 6 in. in thickness or depth but not exceeding 27 in. (68.6 cm), the holding times at the above prescribed temperatures are respectively, 30, 20, and 12 days. The safety factor provided by these regulations has been amply confirmed in years past and more recently by Harrington, Spindler and Hill (1950).[6]

" Several investigators have conducted limited studies on the fate of Trichinella larvae in quick-frozen pork. Augustine (1933) [1] found that quick freezing at –15°C (5°F) for three hours killed Trichinella larvae, whereas slow-freezing at this temperature required 42 hours for destruction ; in both instances the meat was held at –15°C for an additional 48 hours. Augustine (1952) [2] stated that pork can be made safe against trichinosis (1) by lowering the temperature immediately to –35°C (–31°F) or (2) by lowering the temperature first to –18°C (–0.4°F) with subsequent storage for 3 days at the same temperature. Blair and Lang (1934) [3] found that quick-freezing for 3 to 4 hours at –17.8°C (0°F) with continued holding at this temperature for a minimum of 53 hours apparently destroyed Trichinella larvae in pork roasts.

" Gould and Kaasa (1949) [5] conducted more extensive experiments with quick-freezing. Trichinella larvae were destroyed after exposure of infected pork to the following temperatures for the periods stated :

Freezing temperatures °F	°C	*Freezing time*
–16.6	–27	36 hours
–22	–30	24 hours
–27.4	–33	10 hours
–31	–35	40 minutes
–34.6	–37	2 minutes

" Gould (1945) [4] has recommended that all pork produced in the United States be processed for the destruction of trichinae. The New York Academy of Medicine (1948) [7] expressed the view that more fundamental research should be conducted on the potentialities of quick-freezing in this regard. Unless there are available data of which the writer is unaware, the last recommendation would still seem to be a pertinent one. Investigations to date have dealt only with the quick-freezing of small pork cuts, none weighing over approximately 1,800 gm. (4 lb.). The results would certainly not be applicable to the quick-freezing of hog carcasses and probably not applicable to the larger cuts commonly handled in packing-house procedure. Information is needed concerning the minimum temperature and holding time required to provide a safe margin for hog carcasses and large cuts, as well as for pork cuts packed in boxes, tierces, cartons, or other containers commonly used by the trade.

" Before any sensible recommendation can be made for the freezing of all pork (by any method) for the control of trichinosis, not only should we be in possession of the essential technical data, but we should give some consideration to the amount of freezing capacity available and the costs involved. Recommendations concerning quick-freezing must also take into consideration changes induced in the product and consumer taste."

Salt treatment

The United States Government regulations give several methods for salting sausages and other pork products used in the USA. Different salt concentrations, temperatures, and holding times are required, depending on the size and nature of the meat product. (The reader is referred to the original reference [8] for details.)

B. Cysticercosis

The United States Government regulations state that carcasses of hogs affected with *Cysticercus cellulosae* may be passed for cooking, but if the infestation is excessive the carcass is condemned. Also, carcasses of cattle showing a slight or moderate infestation (less than two cysts per cut within an area the size of the palm of the hand) are held in cold storage continuously at a temperature not higher than 15°F (–9.4°C) for a period of not less than 10 days. Boned meat from such carcasses, when in boxes or other containers, is held at the same temperature for not less than 20 days. As an alternative to retention in cold storage, such carcasses and parts may be heated throughout to a temperature of at least 140°F (60°C).

The French regulations (1941) condemn carcasses showing generalized infestation. For " discrete " infestation carcasses can be held for 8 days at –5°C (23°F) or for 30 days at 0°C (32°F). Where refrigeration facilities are unavailable, the meat must be sliced into pieces of 15-cm thickness at most, and either (*a*) cooked at 100°C (212°F) for two hours or (*b*) immersed completely in a salt solution (25° Baumé) for a period of at least 21 days.

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ANNEX 14

DANISH REGULATIONS FOR THE JUDGEMENT OF MEAT *

A. JUDGEMENT CODE ON DISEASES AND PATHOLOGICAL CONDITIONS, 1949

I. General Regulations for Judgement

Article 16

1. *Total condemnation*, i.e., retention and condemnation of the entire carcass and appertaining organs, shall be applied to animals unfit for human consumption on account of generalized disease or local tissue changes or lesions that cannot be removed or which affect the general health of the animal.

2. *Local condemnation*, i.e., retention and condemnation of parts of the carcass, single organs, or parts of organs—with removal of regional lymph-glands if required—shall be applied to localized tissue changes or lesions that have no influence on the general health of the animal concerned.

3. *Conditional approval*, i.e., approval of meat and viscera for human food on condition that they are taken directly to special factories authorized by the Ministry of Agriculture (see Article 42 **), may be given to the meat and viscera of animals presenting such changes or lesions as will not preclude unconditional approval of the meat and offal as fit for human food after they have been treated as prescribed (e.g., heating or, possibly, freezing of carcasses infected with cysticerci).

4. *Unconditional approval*, i.e., approval as suitable for human food, shall be applied to meat and offal definitely fit for human consumption, regardless of the method of preparation (cooking, etc.).

II. Infectious Diseases (Articles 17-20)

Article 17

Malignant Infectious Diseases

1. *Rabies* (hydrophobia): total condemnation of the bitten animal.

2. *Anthrax*, localized or generalized: total condemnation.

* Extracts from the Regulations for the Judgement of Meat drawn up by the Danish Ministry of Agriculture, Veterinary Directorate

** Not reproduced here

Salt treatment

The United States Government regulations give several methods for salting sausages and other pork products used in the USA. Different salt concentrations, temperatures, and holding times are required, depending on the size and nature of the meat product. (The reader is referred to the original reference [8] for details.)

B. Cysticercosis

The United States Government regulations state that carcasses of hogs affected with *Cysticercus cellulosae* may be passed for cooking, but if the infestation is excessive the carcass is condemned. Also, carcasses of cattle showing a slight or moderate infestation (less than two cysts per cut within an area the size of the palm of the hand) are held in cold storage continuously at a temperature not higher than 15°F (–9.4°C) for a period of not less than 10 days. Boned meat from such carcasses, when in boxes or other containers, is held at the same temperature for not less than 20 days. As an alternative to retention in cold storage, such carcasses and parts may be heated throughout to a temperature of at least 140°F (60°C).

The French regulations (1941) condemn carcasses showing generalized infestation. For " discrete " infestation carcasses can be held for 8 days at –5°C (23°F) or for 30 days at 0°C (32°F). Where refrigeration facilities are unavailable, the meat must be sliced into pieces of 15-cm thickness at most, and either (*a*) cooked at 100°C (212°F) for two hours or (*b*) immersed completely in a salt solution (25° Baumé) for a period of at least 21 days.

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ANNEX 14

DANISH REGULATIONS FOR THE JUDGEMENT OF MEAT *

A. JUDGEMENT CODE ON DISEASES AND PATHOLOGICAL CONDITIONS, 1949

I. General Regulations for Judgement

Article 16

1. *Total condemnation*, i.e., retention and condemnation of the entire carcass and appertaining organs, shall be applied to animals unfit for human consumption on account of generalized disease or local tissue changes or lesions that cannot be removed or which affect the general health of the animal.

2. *Local condemnation*, i.e., retention and condemnation of parts of the carcass, single organs, or parts of organs—with removal of regional lymph-glands if required—shall be applied to localized tissue changes or lesions that have no influence on the general health of the animal concerned.

3. *Conditional approval*, i.e., approval of meat and viscera for human food on condition that they are taken directly to special factories authorized by the Ministry of Agriculture (see Article 42 **), may be given to the meat and viscera of animals presenting such changes or lesions as will not preclude unconditional approval of the meat and offal as fit for human food after they have been treated as prescribed (e.g., heating or, possibly, freezing of carcasses infected with cysticerci).

4. *Unconditional approval*, i.e., approval as suitable for human food, shall be applied to meat and offal definitely fit for human consumption, regardless of the method of preparation (cooking, etc.).

II. Infectious Diseases (Articles 17-20)

Article 17

Malignant Infectious Diseases

1. *Rabies* (hydrophobia) : total condemnation of the bitten animal.

2. *Anthrax*, localized or generalized : total condemnation.

* Extracts from the Regulations for the Judgement of Meat drawn up by the Danish Ministry of Agriculture, Veterinary Directorate

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3. *Glanders* : total condemnation.

4. *Equine encephalomyelitis* (infectious paraplegia) : total condemnation.

5. *Equine contagious pleuropneumonia* (malignant lung plague) : total condemnation.

6. *Bovine enzootic meningo-encephalitis* (enzootic meningitis) : total condemnation.

7. *Rinderpest* : total condemnation.

8. *Bovine contagious pleuropneumonia* (lung plague) : total condemnation.

9. *Foot-and-mouth disease* : total condemnation in the acute stage ; conditional approval after the acute stage when the temperature has returned to normal before slaughtering (the head, tongue, and all organs shall be condemned).

10. *Sheep-pox* : total condemnation.

11. *Foot rot* (paranychia contagiosa ovium) : total condemnation in cases of emaciation, sepsis, or pyaemia ; unconditional approval when there are no complications and the animal is well nourished.

12. *Swine fever* (hog cholera) : total condemnation.

13. *Equine infectious anaemia* (acute or chronic) : total condemnation.

14. *Equine epizootic lymphadenitis* (blastomycosis) : total condemnation.

15. *Dourine* (breeding paralysis), acute or chronic : total condemnation.

16. On the occurrence in a slaughter animal of any of the malignant infectious diseases mentioned under headings 1-15, the case shall be instantly reported to the Veterinary Service, and the veterinary officer shall be responsible for the observance of : the regulations laid down in Act 156 of 14 April 1920, governing infectious diseases in domestic animals ; the directions in the relevant instructions to the veterinary police ; and the measures prescribed for prevention of direct or indirect spreading of human or animal infection.

In this respect the duties of the veterinary officer shall include in particular the stipulated confiscation and destruction of meat, offal, and animal products of any kind (skins, hair, hoofs, claws, gastro-intestinal contents, blood, faeces, urine, secretions, etc.) derived from diseased animals or exposed to infection from such animals ; and further, the necessary cleaning and disinfection of personnel, their clothing and tools, and the slaughter-hall, including the floor, the walls, and, if necessary, the atmosphere, as well as contaminated equipment, implements, meat-hooks, etc. When any of the diseases mentioned under 1-15 are discovered, the animal or the

carcass with appertaining organs shall be detained until the case has been reported by telephone to the Veterinary Service.

Article 18

Other Infectious Diseases

1. *Swine erysipelas*: total condemnation in cases of acute erysipelas, diffuse cutaneous erysipelas with erythema, and arthritis, with the following exceptions :

Conditional approval may be given, provided there is no disorder of the general condition of the animal, in cases of healing erythema and of chronic arthritis involving several joints in well-nourished pigs.

Unconditional approval may be given in cases of slight erythema, manifest only by a few superficial healing lesions, and also of chronic arthritis involving only a few joints in well-nourished pigs.

When such conditional or unconditional approval is given, the affected areas of the skin and joints, together with the regional lymph-glands, shall be adequately removed.

Erysipelas endocarditis, see Article 25, paragraph 2 (*b*).

2. *Salmonellosis in all slaughter animals*: total condemnation.

3. *Equine influenza* (catarrhal influenza): total condemnation.

4. *Strangles*: total condemnation in acute febrile cases or when metastasis of the disease has occurred; unconditional approval in afebrile healing cases, possibly after laboratory examination (old encapsulated abscesses of strangles in the mesenteric lymph-glands do not preclude unconditional approval).

5. *Purpura haemorrhagica* (petechial fever): total condemnation.

6. *Bovine group* (fibrinous rhinitis): total condemnation.

7. *Bovine malignant catarrh*: total condemnation.

8. *Blackleg*: total condemnation.

9. *Pasteurellosis* (" stockyard pneumonia ", septic pleuropneumonia): total condemnation.

10. *Coccidiosis and piroplasmosis*: total condemnation.

11. *Enteritis in suckling animals* (including red scours): total condemnation, regardless of the character of the infection.

12. *Diphtheria in calves* (diphtheria vitulorum): total condemnation.

13. *Malignant oedema*: total condemnation.

14. *Tetanus* (lock-jaw): total condemnation.

15. *Septicaemia and pyaemia* : total condemnation.

See also *Osteomyelitis* (Article 33, paragraph 2).

16. *Acute umbilical infection* : total condemnation.

17. *Actinomycosis and actinobacillosis* : total condemnation in case of general debility, emaciation, or metastasis; unconditional approval in localized uncomplicated cases (in the case of actinomycosis in the head or in the lymph-glands of the head, the head shall be condemned, but the tongue may be approved unconditionally if it is free from actinomycosis).

18. *Johne's disease* (paratuberculosis) : total condemnation in case of emaciation, otherwise unconditional approval (the intestines and mesentery shall be condemned).

19. *Fever* : total condemnation (see Article 4, paragraph 2 *).

Article 19

Tuberculosis

A. *In the judgement of tuberculous carcasses particular regard shall be paid to the following conditions :*

1. *Method of spread of the disease.* Distinction is made between local spreading (including spreading by way of the portal and pulmonary circulation) and generalization (spreading through the systemic circulation).

2. *Character and age of tuberculous lesions.* "Old lesions" cover caseation, calcification, or complete encapsulation, showing no active character (haemorrhages, oedema, and recent caseous changes). In the case of avian tuberculosis in the parenchymatous organs of swine, the age of the lesion is judged by its size.

3. *Extent of the disease*

4. *State of nutrition of the animal*

B. *Total condemnation shall be applied in the following cases :*

1. Recent generalization (the presence of numerous miliary lesions in the lungs is regarded as recent generalization).

2. Recent caseous changes together with inflammatory hyperaemia (see A.2 above) in organs or lymph-glands.

3. Older generalized tuberculosis appearing in intermuscular lymph-glands,** bones, joints, or central nervous system, or in the meat.

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** Here the term "intermuscular lymph-glands" includes not only the intermuscular lymph-glands proper, but also the pubic, supramammary, lumbar, and iliac lymph-glands.

4. Widespread tuberculosis of serous membranes.

5. Congenital tuberculosis in suckling animals.

6. Cases of tuberculosis with emaciation or illness of the animal at the time of slaughter.

C. *Conditional approval may be given in the following cases :*

1. Extensive localized processes.

2. Generalized tuberculosis appearing as older processes in organs.

3. Chronic tuberculosis of organs together with old serous lesions of moderate extent on the pleurae or peritoneum or both.

D. *Unconditional approval may be given in the following cases :*

1. When the tuberculosis is definitely localized in one or more organs or their appertaining lymph-glands or both, and when the tuberculous processes are of no great extent and show no acute inflammatory changes (see A.2).

2. Patches of tuberculous pleurisy in cattle when the total area does not exceed the size of the palm of the hand.

3. Generalization appearing merely in the form of a few old processes in organs only.

4. In acute miliary tuberculosis of the liver in swine when the infection has spread through the portal circulation, and when spread through the systemic circulation can be excluded.

E. *Local condemnation and removal*

1. Tuberculous organs and organs with tuberculosis of the regional lymph-glands shall be condemned. In the case of tuberculosis of mesenteric lymph-glands, the mesentery, stomach, and intestines shall be condemned. In the case of tuberculosis of lymph-glands in the head, the head and the root of the tongue shall be condemned, while the tongue shall be dealt with in the same manner as the rest of the carcass. In extensive tuberculosis of the lungs and in pleural tuberculosis, the heart, diaphragm, and oesophagus shall be condemned.

2. In tuberculosis of the lymph-glands of the head in cattle, the retropharyngeal lymph-glands shall be removed ; in swine, all the cervical lymph-glands shall be removed.

In pulmonary tuberculosis or when lymph-glands of the lungs show lesions, the following lymph-glands shall be removed : in cattle, all the lymph-glands in the thoracic cavity (dorsal and ventral mediastinal lymph-glands, sternal lymph-glands) as well as the lymph-glands at the entrance

to the thoracic cavity (caudal deep cervical and costocervical lymph-glands); in swine, the mediastinal lymph-glands in the thoracic cavity as well as the deep caudal cervical lymph-glands.

In less extensive pleural tuberculosis the condemnation shall include the affected part of the thoracic wall with the underlying ribs, which must be excised; in cattle, in addition to the above-mentioned lymph-glands, the sternal, intercostal, and axillary lymph-glands shall also be removed. In the case of more extensive pleural tuberculosis, the entire chest-wall with the underlying ribs shall be condemned and removed. In cases of tuberculous peritonitis, the peritoneum, together with the underlying fatty tissue and the lymph-glands (including the external iliac lymph-glands), as well as both the thin flanks and the diaphragm, shall be condemned and removed.

Article 20

Corynebacterial Infections in Submaxillary Lymph-glands in Swine

Unconditional approval. Provided the diagnosis is established by microscopic and cultural examination, condemnation of the head and removal of the cervical lymph-glands may be omitted. The submaxillary lymph-glands shall be removed and the " lur " * brand may be applied. If the diagnosis is not established by microscopic or cultural examination, the judgement shall be as described under " Tuberculosis " (Article 19, E, paragraphs 1 and 2) and the " lur " brand must not be applied.

III. Tumours

Article 21

1. *Local benign tumours*: unconditional approval with condemnation of the organ or part of the carcass attacked.

2. *Myxofibromas and neurofibromas of intercostal nerves, nerve plexuses, etc.*: total condemnation in the case of widespread tumour formation; unconditional approval in the case of localization of the tumour, when adequate removal of the lesion is practicable.

In the case of tumours on the intercostal nerves, the carcass shall be split, and the brachial and lumbar plexuses shall be inspected after detachment of both shoulders and incision into the rump musculature.

3. *Melanosarcoma*: total condemnation in the case of widespread tumours, metastasis, and resulting emaciation; unconditional approval in

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* Stamp which means " passed for export ".

the case of localization of the tumour, when adequate removal of the lesion is practicable.

4. *Malignant tumours* (carcinoma, sarcoma, etc.): total condemnation in the case of widespread tumour formation, metastasis, and resulting emaciation; unconditional approval in the case of limited tumour formation which has brought about no changes except in the regional lymph-glands.

5. *Leukosis*: total condemnation.

IV. Metabolic Disorders, Deficiency Diseases, and Intoxications

Article 22

1. *General anaemia* (with emaciation cachexia, or hydraemic conditions, including dropsy): total condemnation.

2. *Bovine chronic indigestion* (acetonaemia): total condemnation.

3. *Equine haemoglobinuria*: total condemnation.

4. *Haemoglobinuria in calves* ("bronze calves", congenital porphyrinuria or osteohaematochromatosis): total condemnation in the case of noticeable discoloration.

5. *Uterine paresis*: total condemnation.

6. *Eclampsia*: total condemnation.

7. "*Fatty liver*" *in cows* ("transport disease", intoxication of pregnancy): total condemnation.

8. *Bovine puerperal haemoglobinuria*: total condemnation.

9. *Grass intoxication*: total condemnation.

10. *Beet intoxication*: total condemnation.

11. *Icterus* (jaundice):

(*a*) Icterus of infectious or toxic origin: total condemnation.

(*b*) Icterus due to acute or chronic liver lesions: total condemnation.

(*c*) Physiological icterus in new-born animals, or icterus due to severe haemorrhage (fractures, torsion of the spleen, etc.): total condemnation if the icteric discoloration is still distinct 24 hours after slaughter; otherwise, unconditional approval.

12. *Disseminated melanosis in calves*: total condemnation if satisfactory removal of affected parts is not practicable; otherwise, unconditional approval.

13. *Rickets, osteomalacia, and osteodystrophy* : total condemnation in the case of emaciation, repulsive appearance, or abnormal odour ; unconditional approval in cases with no complications (altered joints and parts of the skeletons shall be condemned).

14. *Acute poisoning* : total condemnation.

15. *Sub-acute or chronic poisoning, with secondary changes* (gastroenteritis, degeneration of organs, etc.) : total condemnation.

V. Abnormal Odour, Taste, or Colour, Sexual Odour, etc.

Article 23

1. *Abnormal odour or taste due to disease* : total condemnation.

2. *Abnormal odour, taste, or colour caused by fodder* (fish, fish-meal, kitchen refuse, etc.) : total condemnation.

3. *Abnormal odour or taste caused by medicinal treatment* : total condemnation.

4. *Sexual odour*

(*a*) *Buck goats* : total condemnation if the carcass smells strongly.

(*b*) *Boars* : the meat shall be marked with a special boar stamp (see Article 43, paragraph 2 *). In the case of a sexual odour or a pronounced boar-like appearance, the boar stamp shall be used also for the meat of cryptorchids and hermaphrodites as well as hog castrates. Meat and offal smelling of boar must not be passed conditionally ; if such meat and viscera cannot be passed unconditionally according to the rules in force, it must be condemned.

5. *Foetuses* (including excised or undeveloped young) : total condemnation.

VI. Diseases of Organs (Articles 24-35)

Article 24

Diseases of the Nervous System

1. *Acute inflammation of the brain and meninges* : total condemnation.

2. *Chronic encephalitis, meningitis, and staggers* : unconditional approval in afebrile cases.

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3. *Brain abscess* : total condemnation if the abscess is due to a pyaemic condition ; in the case of an older, localized brain abscess, with no complications, unconditional approval in afebrile cases.

4. *Affections of the spinal cord and spinal meninges* : treat as lesions of the brain and meninges (see paragraphs 1, 2, and 3 above).

5. *Madness*: The regulations prescribed in Article 13,* governing examination of diseased and emergency-slaughtered animals, shall be followed ; unconditional approval may be given if bleeding is normal and the meat is of good keeping-quality.

Article 25

Diseases of the Pericardium, Heart, and Vessels

1. *Pericarditis*

(*a*) Infectious exudative pericarditis : total condemnation in acute or sub-acute cases ; unconditional approval after laboratory examination in chronic cases without circulatory disturbances in well-nourished animals.

(*b*) Bovine traumatic pericarditis : total condemnation in cases with fever, large accumulation of exudate, circulatory disturbances, degenerative changes in organs, or abnormal odour ; otherwise, unconditional approval after laboratory examination.

(*c*) Healed pericarditis : unconditional approval after local condemnation.

2. *Endocarditis*

(*a*) Ulcerative endocarditis : total condemnation.

(*b*) Verrucose endocarditis (including erysipelas endocarditis) : total condemnation in recent cases, in cases with circulatory disturbances beyond venous congestion in the lungs or in the liver, and in cases of recent infraction, general debility, or poor state of nutrition ; otherwise, unconditional approval after laboratory examination (all the organs shall be condemned).

3. *Heart lesions of non-infectious nature* (malformation of the heart, etc.) : unconditional approval (if some organs or parts of the musculature show evidence of circulatory disturbances, adequate local condemnation shall be applied).

4. *Worm aneurysms*

(*a*) In arteries of the hind leg (see Article 6, " Carcass " *) : unconditional approval (in cases of oedema, infarction, or haemorrhages in the musculature of the hind leg, the leg shall be condemned).

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(*b*) In the cranial mesenteric artery and branches : total condemnation in the case of recent peritonitis, conspicuous circulatory disturbances in the mesentery or intestines, and general debility (see Article 22, paragraph 1) ; otherwise, unconditional approval.

Article 26

Diseases of the Respiratory Passages and Lungs

1. *Sinusitis* : total condemnation in cases with fever or general debility ; otherwise, unconditional approval, with condemnation of the head.

2. *Atrophic rhinitis* (snuffling disease) : unconditional approval, with condemnation of the head, in cases with no complications (the cervical lymph-glands shall be removed) ; in the case of a complication such as pneumonia, pyaemia, osteomyelitis, or otitis media, proceed as directed under these conditions.

3. *Chronic catarrhal or purulent bronchopneumonia* : total condemnation in the case of extensive purulent bronchopneumonia and in catarrhal pneumonia accompanied by disturbance of the general condition or emaciation ; otherwise, unconditional approval, possibly after laboratory examination.

4. *Pleuropneumonia in swine* : total condemnation, except in cases in which pulmonary as well as pleural changes are distinctly healing (organization) and in which no metastasis or evidence of general debility or poor state of nutrition is found, when conditional approval may be given. In cases with older encapsulated areas of necrosis or abscesses, proceed as directed in paragraph 7.

5. *Acute and sub-acute pneumonia in any slaughter animal* (including croupous pneumonia, bronchopneumonia, aspiration pneumonia, gangrene of the lungs, necrotic pneumonia) : total condemnation, except in the case of sub-acute bronchopneumonia in calves and young cattle, when unconditional approval may be given after laboratory examination if the lesion is slight and the animal is well nourished.

6. *Infected emboli (metastasis) in the lungs* (see Article 18, paragraph 15, " pyaemia ") : total condemnation.

7. *Old encapsulated necrotic lesions and abscesses in the lungs* : unconditional approval, provided no metastasis is found and the state of nutrition is good.

8. *Bronchitis* : unconditional approval in cases with no complications (see " bronchopneumonia ", paragraphs 3 and 5).

9. *Atelectasis*, *emphysema*, *pigmentation*, *haemorrhages*, *aspiration of blood*, *of scalding water*, *or of fodder* : condemnation of the lungs.

Article 27

Affections of the Pleura

1. *Secondary pleurisy* : this is considered in relation to the lung lesions with which it is connected.

2. *Diffuse fibrinous, serofibrinous, suppurative, or ichorous pleurisy* : total condemnation (see also paragraph 3).

3. *Fibrinous pleurisy in swine* : total condemnation, except in cases with no complications and with less extensive localized patches of fibrinous exudate, when conditional approval may be given (the chest wall shall be removed adequately and the pluck condemned).

4. *Adhesions and patches of fibrinous tissue* : unconditional approval with condemnation of the lungs and, possibly, the heart (the pleura shall be removed).

Article 28

Diseases of the Stomach and Intestines

1. *Acute gastro-intestinal catarrh in adult animals* : unconditional approval if the animal is free from fever and when examination after slaughter reveals no changes outside the digestive tract other than swollen, but not congested, mesenteric lymph-glands.

In doubtful cases or if some specific intestinal infection is suspected, the carcass may be passed only after laboratory examination. In cases of extensive congestion of the gastro-intestinal mucosa, congested or markedly swollen mesenteric lymph-glands, enlargement of the spleen, or degeneration of organs, the animal is dealt with as in paragraph 3.

2. *Chronic gastric and intestinal catarrh* : total condemnation in the case of emaciation, degeneration of organs, or abnormal odour ; otherwise, unconditional approval (see Article 36, paragraph 6).

3. *Septic, croupous, diphtheritic, or haemorrhagic enteritis* : total condemnation.

4. *Constipation and changes in position* (including colic in the horse) : total condemnation in acute severe cases (ileus, constipation of the small intestine, volvulus, invagination, incarceration) (see Article 29), and in rather severe or complicated cases of constipation of the colon or caecum ; unconditional approval in mild cases of uncomplicated constipation of the colon or caecum in the horse.

5. *Tympany and impaction of the stomach or rumen* : total condemnation.

6. *Emphysema of the mesentery* (in swine) : unconditional approval, with condemnation of the gut and mesentery involved.

Article 29

Affections of the Peritoneum

1. *Peritonitis* : total condemnation in the case of acute diffuse or extensive exudative peritonitis and in the case of localized peritonitis with signs of general debility (fever, enlargement of the spleen, degeneration of organs, etc.) ; unconditional approval after laboratory examination in the case of fibrinous peritonitis of limited extent and undoubtedly local nature.

2. *Adhesions and patches of fibrinous tissue, and localized encapsulated abscesses* : unconditional approval, with local condemnation and, if required, adequate removal of the peritoneum.

Article 30

Diseases of the Liver

1. *Telangiectasis, cyst formation, gallstones* : unconditional approval, with condemnation of the whole or part of the liver according to the extent of the affection.

2. *Fatty infiltration*

(*a*) Localized fatty infiltration : unconditional approval, with condemnation of the whole or part of the liver according to the extent of the affection.

(*b*) Diffuse, simple (physiological) fatty infiltration : unconditional approval, including the liver.

(*c*) Degenerative fatty infiltration : see paragraph 3.

3. *Degeneration of the liver* (parenchymatous degeneration, degenerative fatty infiltration, and amyloid degeneration) : total condemnation (see infectious diseases, poisoning, etc.).

4. *Hepatitis* : total condemnation in cases of acute or sub-acute hepatitis of infectious, toxic, or parasitic nature (including, for instance, toxic dystrophy, acute cysticercosis, and acute distomatosis—see Article 36, paragraph 9), and in cases of chronic hepatitis (cirrhosis of the liver) accompanied by emaciation, circulatory disturbances, jaundice, or abnormal odour ; unconditional approval (with condemnation of the liver) in the case of chronic hepatitis (cirrhosis of the liver) without the above-mentioned complications, and when the state of nutrition is good.

5. *Parasitic nodules in the liver* : see Article 36, paragraph 5.

6. *Recent bacterial necrosis of the liver* : total condemnation in the case of multiple necrotic areas ; otherwise, unconditional approval, with condemnation of the liver.

7. *Abscesses of the liver*

(*a*) Embolic abscesses of the liver associated with recent umbilical infections, or traumatic abscesses in the spleen, etc. : total condemnation.

(*b*) Old encapsulated abscesses of the liver : unconditional approval, with condemnation of the liver.

8. *Miliary necrosis of the liver* (paracolibacillosis) : total condemnation (see Article 18, paragraph 2, " Salmonellosis ").

Article 31

Diseases of the Urinary Tract

1. *Renal calculi, cyst formation, pigmentation* : unconditional approval, with condemnation of the whole or part of the kidneys according to the extent of the affection.

2. *Nephritis* : total condemnation in cases of nephritis accompanied by emaciation or signs of renal insufficiency (odour of urine, uraemia, hydraemia) ; unconditional approval, with condemnation of the kidneys, in cases of chronic nephritis without the above-mentioned complications (e.g., chronic glomerulonephritis in cattle, chronic interstitial nephritis in cattle and swine, disseminated lympho-leukocytic nephritis in swine, " motley kidney " (white spot) in calves).

3. *Disseminated leukocytic nephritis* (colinephritis)

(*a*) Bobby calves : total condemnation.

(*b*) Veal calves and adult cattle : unconditional approval with condemnation of the kidneys, in cases with no complications.

4. *Suppurative and embolic nephritis* (see Article 18, paragraph 15, " pyaemia ") : total condemnation.

5. *Pyelonephritis in cattle* : total condemnation in advanced cases showing a poor state of nutrition or signs of renal insufficiency (see paragraph 2) ; otherwise, unconditional approval, with condemnation of the kidneys and bladder.

6. *Cystitis* : total condemnation in the case of exudative forms of cystitis accompanied by fever, general debility, odour of urine, or urinogenous pyelonephritis ; otherwise, unconditional approval.

7. *Rupture of the bladder or urethra* : total condemnation in cases of urinogenous peritonitis, odour of urine, or urinary cellulitis ; otherwise, unconditional approval.

Article 32

Diseases of the Genitalia and Mammary Glands

1. *Inflammation of the uterus*

(*a*) Acute metritis (including croupous, diphtheritic, necrotic, and septic metritis, as well as the presence of putrified foetuses in the uterus) : total condemnation.

(*b*) Chronic metritis (including pyometra and the presence of macerated foetuses in the uterus) : total condemnation in the case of emaciation or when the disease is accompanied by fever, general debility, or degeneration of organs ; unconditional approval after laboratory examination in cases free from the above-mentioned complications, but with either large accumulations of pus in the uterus or with accumulation of serofibrinous fluid in joints and tendon sheaths.

(*c*) Chronic uterine catarrh, with minor accumulations of pus or with mummified foetuses in the uterus : unconditional approval.

2. *Retention of placenta* : total condemnation when the disease is accompanied by fever, general debility, or acute inflammatory changes in the uterus ; otherwise, unconditional approval after laboratory examination.

3. *Brucellosis* : unconditional approval.

When *Brucella* infection of the uterus or male genitals is discovered, the organs concerned shall be condemned, together with the udder, and the iliac, sub-lumbar, ischiatic, and superficial inguinal (or supramammary) lymph-glands shall be removed.

4. *Incomplete delivery* : total condemnation if the condition is complicated by acute metritis or wound infection in the obstetric canal (malignant oedema, necrotizing vaginitis) and in the presence of putrified foetuses ; otherwise, unconditional approval after laboratory examination.

5. *Prolapse, torsion, and rupture of the uterus* : total condemnation if the case is complicated by fever or acute peritonitis ; otherwise, unconditional approval after laboratory examination. Unconditional approval may also be given in recent uncomplicated cases of torsion with the cervix closed.

6. *Hydrops of the uterus* : total condemnation in the case of emaciation ; otherwise, unconditional approval.

7. *Inflammation of the udder* (mastitis) : total condemnation in cases of septic or gangrenous mastitis and in the presence of fever, general debility, emaciation, or degeneration of organs ; unconditional approval after laboratory examination in cases of chronic purulent mastitis with pronounced retention of pus or when there are serofibrinous accumulations

in joints and tendon sheaths, and also in uncomplicated cases of chronic catarrh and purulent or abscess-forming mastitis, and in cases of encapsulated sequestra. In such cases, the approval is subject to removal of the supramammary and iliac lymph-glands.

8. *Pigmentation of the mammary glands in swine*: total condemnation.

Article 33

Affections of Bones, Joints, and Tendon Sheaths

1. *Fractures*

(*a*) Infected fractures: total condemnation.

(*b*) Non-infected, recent, or healing fractures: unconditional approval, with condemnation and removal of the site of fracture and blood-infiltrated tissue.

2. *Osteomyelitis*: total condemnation in cases of ichorous or suppurative osteomyelitis originating from, or causing, metastasis, or accompanied by fever or general debility; unconditional approval in the case of a suppurative process involving a bone with no complications, though subject to laboratory examination unless the process is encapsulated by fibrous tissue.

3. *Otitis media*: total condemnation if accompanied by the complications mentioned under osteomyelitis; otherwise, unconditional approval, with condemnation of the head.

4. *Deposits of pigment in bones and periosteum*: unconditional approval, with local condemnation and removal of all bones according to the extent of the pigmentation.

5. *Inflammation of joints* (arthritis)

(*a*) Non-infectious arthritis: unconditional approval, with local condemnation.

(*b*) Infectious arthritis (fibrinous or purulent):

(1) arthritis in two or more joints (multiple arthritis, see Article 18, paragraphs 15 and 16): total condemnation;

(2) arthritis in only one joint:

(i) in suckling animals: total condemnation;

(ii) in other animals: total condemnation if the affection is accompanied by fever; otherwise, *unconditional approval* after laboratory examination.

(*c*) Chronic arthritis in swine: see Article 18, paragraph 1, "erysipelas".

6. *Inflammation of tendon sheaths*: judgement as in the case of arthritis.

7. *Presternal calcification in cattle* : local condemnation.

Article 34

Diseases of the Musculature

1. *Calcareous deposits* : total or local condemnation according to the extent of the affection (see also Article 36, paragraphs 1, 7, and 11).

2. *Aseptic necrosis of musculature in swine* : local condemnation.

3. *Pseudotuberculosis in the musculature, etc., in the carcasses of adult cattle* : total condemnation.

4. *Degeneration of muscles without any demonstrable connexion with other diseases*

(*a*) Horse, ox, sheep, and goat : total condemnation.

(*b*) Swine : total condemnation when the entire musculature has undergone degeneration or the animal has fever. Condemnation of the meat, with unconditional approval of the fat and organs, when a considerable part of the musculature (back, shoulder, ham, and psoas muscles) is involved ; unconditional approval, with local condemnation, when the affection is limited.

Article 35

Skin Affections

1. *Wounds and cellulitis*

(*a*) Recent or granulating wounds and scars : unconditional approval, with local condemnation.

(*b*) Infected wounds and phlegmons : total condemnation in the case of complication by fever, metastasis (see Article 18, paragraph 15, " pyaemia "), or sepsis ; otherwise, unconditional approval after laboratory examination.

2. *Contusions* (bruising) : unconditional approval, with local condemnation, in cases with no complications.

3. *Burns* : total condemnation in the case of burns accompanied by extensive oedema, degeneration of organs, fever, pseudomembranous tracheobronchitis, bronchopneumonia, or odour of smoke in the meat ; unconditional approval after laboratory examination in cases with no complications.

4. "*Shotty*" *eruption in swine*: unconditional approval, with local condemnation of the skin areas attacked.

5. *Eczema and chronic dermatitis in swine*: judgement must be based on whether the skin lesion is of a primary or a secondary nature.

Total condemnation in the case of primary skin lesions accompanied by emaciation; otherwise, unconditional approval after removal of the altered skin areas together with the regional lymph-glands. In secondary skin lesions associated with chronic lesions of organs or metabolic disease (e.g., rickets), the skin affection is to be taken into consideration as an aggravating factor.

6. *Erythema* (frostbite, sunburn, corrosions): unconditional approval, with local condemnation of the altered skin areas, together with the regional lymph-glands, in afebrile cases with no complications.

7. *Sarcoptic mange in swine*: total condemnation if the lesion is very extensive and the animal is emaciated; otherwise, unconditional approval, with condemnation of the skin areas attacked, together with the regional lymph-glands.

In the case of scabies of the head or toes, these parts shall be condemned.

8. *Psoroptic scab in sheep* (see Article 17, paragraph 16): total condemnation if the animal is emaciated or if suppurative inflammatory processes are found in the skin; otherwise, unconditional approval.

9. *Ringworm*: unconditional approval (see Article 22, paragraph 1). When the lesion is localized to the head in calves the head shall be skinned or condemned, according to the extent of the affection.

VII. Internal Parasitic Diseases

Article 36

1. *Cysticercus bovis*: total condemnation when more than ten clear and/or degenerated cysticerci are found; conditional approval when up to ten clear and/or degenerated cysticerci are found (the carcass and organs shall be dealt with in accordance with the regulations prescribed in Article 42: * if freezing is employed (see Article 42, paragraph 2) this shall be done at a temperature not higher than –10°C for at least 10 days); unconditional approval can be given, however, when up to ten completely degenerated cysticerci are found in cattle over two years old (i.e., with at least one broad tooth).

* Not reproduced here

In the case of animals with cysticerci, condemnation shall always include the head, heart, diaphragm, oesophagus, organs with cysticerci, and the tongue if it is sliced for examination. Cysts in the carcass shall be cut out. In cases of conditional approval, the stomach, intestines, and fat can be approved unconditionally.

2. *Cysticercus cellulosae* : total condemnation.

3. *Trichinosis (Trichinella spiralis)* : total condemnation (see Article 13 of Act No. 156 of 14 April 1920,* governing infectious diseases in domestic animals).

4. *Echinococcus, Coenurus cerebralis, and Cysticercus tenuicollis* : unconditional approval, with condemnation of the whole or part of any organ attacked, according to the number of parasites.

5. *Parasitic nodules in the liver* : condemnation of the whole or part of the liver, according to the extent of the lesion.

6. *Pulmonary and gastro-intestinal strongylosis, as well as tapeworms and other worms in the digestive tract, in the horse, ox, sheep, goat, and pig* : total condemnation if the affection has caused anaemia, hydraemia, or emaciation ; otherwise, unconditional approval, with local condemnation so far as necessary.

7. *Strongylus larvae beneath the serosa covering the subperitoneal fat in the horse* : unconditional approval, with local removal or condemnation of the subperitoneal fat.

8. *Parasitic nodules in the intestines* : condemnation of the entire intestine or the affected section if more than a few scattered nodules are found.

9. *Liver fluke*

(*a*) Acute distomatosis : total condemnation in the presence of complications (see Article 30, paragraph 4) or general debility ; unconditional approval in the case of limited invasion without complications.

(*b*) Chronic distomatosis : total condemnation if the affection has caused anaemia, hydraemia, or cachexia (see Article 22, paragraph 1) ; otherwise, unconditional approval with condemnation of the liver if it cannot be trimmed adequately.

10. *Larval infestation*

(*a*) In cattle (warble-fly) : unconditional approval, with removal of parts affected by the parasite (musculature of the back, spinal canal, oesophagus).

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* Not reproduced here

(*b*) In horses (*Gastrophilus* infestation): excision of the gullet if larvae are present in it.

(*c*) In sheep (*Oestrus ovis* infestation): condemnation of the head.

11. *Calcified sarcosporidia* : total condemnation when the parasites are found in great number throughout the musculature ; unconditional approval if adequate trimming can be performed. If sarcosporidia are found in the oesophagus of sheep or goats, the affected part shall be condemned.

VIII. Emergency-slaughtered and Dead Animals

Article 37

1. *Emergency slaughter*: judgement shall be made according to the disease present, in compliance with the foregoing regulations, with total condemnation in the case of insufficient bleeding, discoloration, or oedematous conditions.

B. RULES AND INSTRUCTIONS FOR LABORATORY METHODS OF EXAMINATION AND THEIR APPLICATION IN THE HYGIENIC JUDGEMENT OF CARCASSES, 1954

1. *Samples*

The following samples should be sent to the laboratory:

(*a*) The spleen (intact whenever possible).

(*b*) A piece of liver (about 500 g) taken from the hilar region, together with portal lymph-nodes and gall-bladder (empty).

(*c*) Two intact lymph-nodes (prescapular, prefemoral, popliteal, ischiatic).

(*d*) A piece of muscle covered by intact fascia (at least 250 g), preferably taken from the extensor muscles of the forearm. In pigs, the whole forearm with skin should be cut off as close to the elbow as possible.

(*e*) Where special pathological findings make it advisable to have any other organ included in the examination, a fairly large piece of the organ, including its lymph-nodes (intact), should be sent with the routine samples.

2. *Precautions in taking of samples*

The samples must be taken as soon after slaughter as possible, using clean and sterilized (scalded) instruments. No incisions should be made in the lymph-nodes and the samples must be protected against contamination throughout.

3. *Shipment*

Before being wrapped, the samples must be cooled effectively (by refrigeration). After cooling, each sample should be wrapped separately in several layers of clean absorbent paper (e.g., newspaper). Parchment or heavy wrapping paper should not be used for the wrapping of the individual samples. After wrapping, the samples should be packed in a cardboard or wooden box. Tight metal containers must not be used.

The samples must be accompanied by a written form stating ante-mortem findings (body temperature; symptoms, if any; duration of disease; medical treatment) and post-mortem findings, the exact hour of killing, and identification number and name.

Shipment to the laboratory must be by the fastest means available.

4. *Judgement*

Final judgement must be withheld until the results of the laboratory findings are received and should not be given earlier than 48 hours after slaughter. Before the carcass is finally passed, the meat inspector must re-inspect it. It is most important that he should evaluate the state of freshness of the meat at the time of re-inspection.

Laboratory Techniques

A. Bacteriological examination

This examination is performed by cultivating material taken aseptically from the samples in the media listed below. The purpose of the examination is to provide information on the bacteriological status of the meat (muscle), the lymph-nodes, and the organs.

1. *Apparatus and equipment*

A wooden board covered with clean filter-paper and metal pins for fixing the samples; a gas burner and a hot iron spatula to sterilize the surfaces of the tissues by burning; knives, preferably with changeable blades; scissors; instrument boiler; sterile Petri dishes and tubes (180 mm × 22 mm); general equipment for bacteriological work.

2. *Media*

(*a*) Blood agar: broth-peptone agar (pH 7.6) plus 5% sterile defibrinated blood.

(*b*) Bromothymol-blue/lactose/saccharose agar: to one litre of meat-extract/peptone agar (pH 7.6) is added aseptically a solution consisting of 10 g of lactose plus 10 g of saccharose dissolved in 80 ml of 0.005 N sodium hydroxide containing 0.25% bromothymol blue and sterilized at 110°C for 15 minutes. No re-sterilization of the finished medium.

(*c*) Glucose agar: broth-peptone agar (pH 7.6) plus 0.5% of glucose. The glucose is dissolved in distilled water, sterilized at 110°C for 15 minutes, and then added aseptically to the agar medium. No re-sterilization.

(*d*) Brilliant-green/lactose/saccharose/phenol-red agar: 10 g of peptone, 5 g of meat extract, 5 g of sodium chloride, and 20 g of agar are dissolved in 1000 ml of water by boiling for 30 minutes at 110°C. Filtration through flannel. Adjustment of pH to 7.2. Sterilization for 30 minutes at 110°C. To 1000 ml of melted agar medium is added aseptically a solution consisting of 10 g of lactose and 10 g of saccharose in 80 ml of 0.005 N sodium hydroxide containing 1% phenol red. This solution has been sterilized by boiling at 100°C for 10 minutes. Finally, 2 ml of a 0.5% brilliant-green solution is added. No re-sterilization.

(*e*) Selenite broth: 4 g of sodium selenite ($NaHSeO_3$, $5H_2O$), 5 g of peptone, and 10 g of disodium hydrogen phosphate (Na_2HPO_4, $12H_2O$) are dissolved in 1000 ml of water and filtered. Sterilization at 110°C for 30 minutes. 4 g of lactose dissolved in a small quantity of distilled water and sterilized at 110°C for 15 minutes are added aseptically.

Tetrathionate broth may be used instead of selenite broth.

3. *Inoculation of media*

The samples must be fixed to the wooden board by means of the metal pins or by applying a suitable forceps. The samples of muscle from pigs must have the skin removed. Fatty tissues are removed from the surfaces of the lymph-nodes. The surfaces through which incisions are to be made must be sterilized by means of the hot iron spatula. Knives and scissors are sterilized by boiling or flaming. Pieces of the tissues, about the size of an almond, are removed aseptically from the interior layers of the tissue and transferred to the various media as follows (from the gall-bladder, scrapings of the mucosa are used for the inoculation):

Muscular tissue and lymph-nodes	Blood agar (Petri dish) Bromothymol-blue/lactose/saccharose agar (Petri dish) Deep glucose-agar tubes Selenite-broth or tetrathionate-broth tubes

Spleen	Blood agar (Petri dish) Bromothymol-blue/lactose/saccharose agar (Petri dish) Deep glucose-agar tubes Selenite-broth or tetrathionate-broth tube
Liver, liver lymph-nodes and gallbladder	Selenite-broth or tetrathionate-broth tube (mixed sample)

To control the sterility of the blood-agar medium, pour one non-inoculated Petri dish. The material which is transferred to selenite or tetrathionate broth must be crushed against the wall of the tube by means of a knife. The material from muscle, spleen, and lymph-nodes which has been transferred to empty Petri dishes must be smeared against the bottom of the Petri dish in order to disperse part of the tissue material in the medium, while the bulk of the tissue block is left to be embedded in the medium. Melted blood-agar and bromothymol-blue/lactose/saccharose agar are poured into the plates. The deep glucose-agar tubes must be inoculated while the medium is melted and cooled down to about 45°C. After the inoculation the tubes are placed in cold water for the agar to solidify.

4. *Incubation*

All cultures are placed in the incubator at 37°-38°C, and a first reading is made after 16-18 hours. If the selenite- or tetrathionate-broth tubes show growth, a few drops are streaked on a brilliant-green/lactose/saccharose/phenol-red agar plate for the isolation of salmonellae. When readings of the agar plates and glucose-agar tubes are negative, a second reading must be made after further incubation for an additional 24 hours. An incubation period of 40-48 hours is essential for the cultural demonstration of species such as *Erysipelothrix* and *Corynebacterium pyogenes*. Moreover, these organisms are very often found to have multiplied only within the embedded tissue-block itself, without giving rise to any visible colonies in the surrounding medium. All plate cultures found to be negative after 48 hours of incubation must therefore be examined microscopically. Gram-stained smears are prepared from the tissue blocks and examined for the presence of *Erysipelothrix* and *Corynebacterium pyogenes*.

5. *Identification of positive cultures*

The identification should be based upon colony morphology, haemolysis in the blood-agar plate, fermentation reactions in the bromothymol-blue agar plate, plus microscopic examination of Gram-stained slides, etc. Formation of gas in the deep glucose-agar tubes, combined with butyric acid or putrid smell, and, eventually, lack of growth in the aerobic cultures, indicate the presence of clostridia. Colonies suspected of being salmonellae

(red colonies in brilliant-green/phenol-red agar, blue colonies in bromothymol-blue agar showing Gram-negative rods) must be identified by means of the slide-agglutination test (mixed O-serum). The triple sugar-iron-agar slants are also valuable for rapid presumptive identification of various Gram-negative bacteria. When anthrax is suspected, the Ascoli test should be applied to extracts of the tissues (see Appendix, page 470).

Types of bacteria. Bacteria found in bacteriological meat examination may be either pathogenic bacteria or a mixed flora of non-pathogenic bacteria, resembling the natural intestinal flora. The term " specific infection " covers findings of all species regarded as specific pathogens : haemolytic streptococci, *Diplococcus lanceolatus*, haemolytic staphylococci, *Pasteurella*, *Salmonella*, *Escherichia* in newborn animals, *Bacillus anthracis*, *Erysipelothrix*, *Listerella*, and *Corynebacterium pyogenes*.

The term " non-specific infection " covers findings of species of non-pathogenic or only potentially pathogenic bacteria : streptococci of the viridans group, enterococci, *Escherichia* in grown-up animals, *Clostridia*, bacilli of the *subtilis-mesentericus* group, and non-haemolytic staphylococci.

6. *Reporting and interpretation of results*

Results are classified as follows :

(*a*) Samples sterile ;

(*b*) Specific infection (species, localization) ;

(*c*) Low-grade non-specific infection (growth from one sample only, liver not counted) ;

(*d*) High-grade non-specific infection (growth from two or more samples, liver not counted).

Results named under (*a*) and (*c*) are no hindrance to passing the carcass.

Results named under (*b*) and (*d*) necessitate condemnation.

B. Measurement of pH of muscle

This test must be postponed until at least 24 hours after the slaughter of the animal. For the determination of pH, material is taken from the same muscle as that used for bacteriological examination.

1. *Methods*

The following two methods may be employed :

(*a*) *Electrometric determination*

This method makes use of a potentiometer (glass electrodes). By means of a knife, about 10 g of muscular tissue are scraped from the internal layers of the muscle. The material is transferred to a beaker and mixed with an

approximately equal quantity of distilled water. After standing for about 10 minutes at room temperature, the mixture is ready for pH measurement. The electrodes are placed directly into the water-meat mixture.

(*b*) *Nitrazine-yellow indicator test*

Reagent. An aqueous solution of nitrazine-yellow indicator, 1/10 000.

Procedure. The yellow indicator solution is poured into a small, shallow, white porcelain dish, and a small piece of muscular tissue is then placed in the dish. The tissue being pressed and squeezed with a knife, some tissue fluid will escape and mix with the indicator solution. If a dark violet colour develops, the pH is above 6.5. Well below that point no change in colour takes place. At pH values close to 6.5 a greenish colour will appear.

2. *Reporting and interpretation of results*

pH readings above 6.5 (or definite violet colour of nitrazine-yellow indicator) are considered as evidence of a low keeping-quality of the meat, and the meat inspector will have to consider carefully the state of freshness of the carcass. Ordinarily, such meat can at best be classified as " conditionally passed ", which means that the meat is not allowed to enter the ordinary market, but is handed over, under the direct supervision of the meat-inspection services, for processing in special factories, where it is used for sterilized canned products. In this way, meat known to possess a keeping quality below standard can be kept off the fresh-meat market.

Appendix

ASCOLI PRECIPITATION TEST FOR ANTHRAX

This test is very useful, particularly for the examination of hides suspected of originating from animals infected with anthrax. The success of the test depends, however, upon the employment of potent precipitating serum and careful technique on the part of the laboratory worker. Precipitating serum is best prepared in donkeys. Strains of micro-organisms vary widely in their ability to act as antigens in the hyperimmunization of donkeys. Strains of *Bacillus cereus (anthracoides)* have been found to serve as the best antigens. It is often necessary to try several strains before a good antigenic strain is found. Briefly, thick suspensions in saline are made of agar-slant growths of the different strains of micro-organisms being tested. The suspensions are boiled for a few minutes, cooled, and filtered, and the clear filtrate is stratified with precipitating serum of known potency. Such serum can be obtained from the Institut Pasteur, Paris, and from the Istituto Sieroterapico Milanese Serafino Belfanti, Milan.

ANNEX 15

REGULATIONS OF THE COLONY AND PROTECTORATE OF KENYA FOR MEAT INSPECTION *

1. . . .

2. In these Rules, unless the context otherwise requires :

" carcass " includes any part of a carcass and its viscera ;

" Code of Practice " means the Code of Practice of Meat Inspection set forth in the Schedule to these Rules ;

" designated place " means any abattoir, slaughterhouse, or other place declared to be such under rule 3 of these Rules ;

" Health Inspector " means any Health Inspector appointed by the Government holding the certificate of the Royal Sanitary Institute (England) or the Royal Sanitary Association of Scotland, for Inspectors of Meat and other foods ;

" Inspecting Officer " means any Medical Officer of Health, Veterinary Officer or Health Inspector, and includes any other person duly authorized by any of the said persons to assist him for the purposes of these Rules ;

" Medical Officer of Health " means the Medical Officer of Health for the area in which the designated place concerned is situated ;

" Minister " means the member of the Council of Ministers of the Colony for the time being responsible for public health matters ;

" Veterinary Officer " means a Veterinary Surgeon in the service of the Government.

3. The Minister may, by notice in the Gazette, declare any abattoir, slaughterhouse or other place where live-stock is slaughtered for the purpose of human consumption to be a designated place for the purpose of these Rules.

4. Except in an emergency, any person who slaughters, at a designated place, any live-stock which has not, prior to such slaughter, been inspected by a Veterinary Officer in accordance with the Code of Practice shall be guilty of an offence against these Rules.

5. Any person who parts with possession or control of the carcass of any live-stock slaughtered at a designated place, being a carcass which has

* The Public Health (Designated Places—Meat Inspection) Rules, 1955, drawn up under the Public Health Ordinance by the Governor in Council of Ministers of the Colony and Protectorate of Kenya.

not, prior to such parting with possession or control, been inspected in accordance with the Code of Practice by a Medical Officer of Health, Veterinary Officer or Health Inspector shall be guilty of an offence against these Rules unless it is shown to the satisfaction of a Medical Officer of Health, Veterinary Officer or Health Inspector that the carcass is not intended for human consumption.

6. It shall be lawful for the Medical Officer of Health or any Veterinary Officer or Health Inspector to detain and to order the disposal or destruction of any live-stock or carcass which, in his opinion, is unfit for human consumption.

7. Any person, other than an Inspecting Officer, who attaches, removes or alters any tag, token or mark, used in the process of inspection of any live-stock or carcass under the Code of Practice, from such live-stock or carcass shall be guilty of an offence against these Rules.

8. Any person who removes or disposes of any live-stock or carcass which has been so marked or tagged except with consent or in accordance with the instruction of a Medical Officer of Health, Veterinary Officer or Health Inspector shall be guilty of an offence against these Rules.

9. Any person who obstructs or hinders an Inspecting Officer acting in the course of his duties as such shall be guilty of an offence against these Rules.

10. Any person who commits an offence against these Rules shall be liable on conviction to a fine not exceeding two thousand shillings.

11. These Rules shall not apply so as to interfere with the operation or effect of the Animal Diseases Ordinance or anything lawfully done thereunder.

SCHEDULE

CODE OF PRACTICE OF MEAT INSPECTION

Ante-mortem Inspection

1. (1) All cattle, sheep, swine, and goats shall be inspected ante mortem except in cases of emergency.

(2) No animal which has entered the yards or lairages shall be removed therefrom, whether for slaughter or otherwise, unless permission in writing is granted by the inspecting officer.

(3) The ante-mortem inspection shall be carried out if possible on the unloading ramp or in lairages, provided the latter have ample natural light.

(4) During the inspection the following details shall be noted:

(*a*) disease symptoms which may influence the general health of the animal or depreciate the meat;

(*b*) the presence of notifiable infectious diseases or symptoms which may suggest that such disease is developing;

(*c*) species, sex, colour, age, behaviour, body temperature.

(5) In particular attention should be paid to the following:

(*a*) condition of nutrition;

(*b*) manner of standing and walking;

(*c*) reaction to environment;

(*d*) hide, skin and hair;

(*e*) digestive system (lips, mouth, anus, rumination, quality of faeces, appetite);

(*f*) vulva, vagina, mammary gland;

(*g*) respiratory system (nasal openings, respiration).

2. (1) Every animal suspected on ante-mortem inspection shall be set apart and tagged as a " SUSPECT " and slaughtered either in the casualty block or when the killing of the normal animals has been completed.

(2) Any inspecting officer carrying out the ante-mortem inspection shall notify in writing the officer in charge or the officer(s) on the killing-floor of the reason why the animal has been classed as " SUSPECT ".

3. Any animals showing on ante-mortem inspection a disease or condition that would necessitate condemnation of the carcass on post-mortem inspection shall be tagged as " CONDEMNED ".

4. " CONDEMNED " animals shall, if not already dead, be killed in the post-mortem room only and shall not be conveyed into any department of the establishment used for edible products.

Post-mortem Inspection

5. (1) The post-mortem inspection shall follow as soon as possible after the slaughter of the animal, except in cases of emergency slaughter.

(2) The carcass shall not be cut up into quarters until the inspecting officer has carried out his examination.

(3) All hair, scurf and dirt, and hoofs and claws, shall be removed from pig carcasses and the carcasses shall be thoroughly washed and cleaned before any incision is made for inspection or evisceration.

(4) When a carcass is to be dressed with the skin or hide left on, the skin or hide shall be thoroughly washed and cleaned before any incision is made for the purpose of removing any part thereof or evisceration, except that where calves are slaughtered by the Jewish or Mohammedan method, the heads shall be removed from the carcasses before washing of the carcass.

(5) No serous membrane shall be removed, nor shall any evidence of disease be modified or obliterated by washing, scraping or stripping or in any other manner before inspection by an authorized officer.

(6) The organs of the abdomen, pelvis, and thorax shall be removed, and the tongue in calves and pigs. The head and feet may be cut off, if so desired, from cattle, sheep, and goat carcasses. Ears, eyes, sexual organs, the navel in pigs, and the anus shall be removed immediately.

(7) If several animals of the same species are slaughtered together, the parts and organs removed from a carcass shall be kept beside that carcass or otherwise marked to facilitate their identification with the carcass from which they have been removed.

(8) No part or organ shall be removed without the knowledge and permission of the inspecting officer before the inspection of the carcass and viscera is fully completed.

6. (1) Every Inspecting Officer shall possess at least two knives which shall be kept in clean condition. Knives which are soiled by diseased matter shall not be used until they have been properly cleaned and disinfected.

(2) Every Inspecting Officer shall incise all the organs and parts of a carcass. If the routine incisions are not sufficient to reach a diagnosis, the Inspecting Officer may incise other parts or demand the cutting-up of the carcass.

(3) When incising diseased parts, every Inspecting Officer shall avoid contaminating the healthy parts of the carcass or organs, and the floor, etc.

(4) Any carcass, organ, or part retained for further inspection or bacteriological examination shall be marked by the Inspecting Officer with a label stating "RETAINED". The carcass, organ, or part shall be removed to a detention room where it will remain until a final decision has been reached. The identity of every such retained carcass, organ, or part shall be maintained until the final inspection has been completed.

(5) Where a slaughtered animal is found by the Inspecting Officer to be free from disease, well-nourished, and in sound and wholesome condition, the carcass shall be passed as fit for consumption and it shall be stamped by the Inspecting Officer with the official mark of approval.

(6) The remainder of a carcass from which diseased parts have been taken by, or under the personal supervision of, an Inspecting Officer shall be passed as fit for consumption and stamped by the Inspecting Officer with the official mark of approval.

7. (1) The carcass shall be examined visually to ascertain the following:

(*a*) condition of nutrition;

(*b*) evidence of bruising, haemorrhage, injuries, or discoloration;

(*c*) efficiency of bleeding;

(*d*) local or general dropsy (oedema);

(*e*) abnormalities, swellings, or deformities of bones, joints, muscles, or other tissues;

(*f*) conditions of serous membranes (pleura and peritoneum).

(2) Viscera shall be examined either *in situ* or as they are removed from the carcass.

(3) Lymph-nodes shall be examined by palpation and deep multiple, longitudinal incisions (if required they shall be removed for detailed inspection).

(4) The carcass muscles shall be inspected by viewing and incision.

(5) Any carcass, organ, or part demanding a more detailed examination shall be retained in accordance with the provisions of sub-paragraph (4) of paragraph 6.

(6) Any incision or excision shall be made if possible in such a manner as not to impair the market value of the carcass, organ, or part.

8. A visual inspection alone or together with palpation and/or incision of the undermentioned parts or organs shall be carried out as a routine measure:

(*a*) blood—(*note*: colour, clotting, staining ability, presence of foreign matter);

(*b*) head—(pharynx, tongue, lips, sub-maxillary and retropharyngeal lymph-nodes);

(*c*) lungs—(trachea, bronchial and mediastinal lymph-nodes);

(*d*) heart—(peri-, ecto- and endocardium—routine incision of heart muscle in accordance with the provisions of paragraph 9);

(*e*) diaphragm;

(*f*) liver—(surface and substance, bile ducts, and lymph-nodes);

(*g*) stomach and intestines—(omentum, mesentery, mesenteric lymph-nodes);

(*h*) kidneys—(surface and substance, and if necessary renal lymph-nodes);

(*i*) spleen—(incision only if necessary);

(*j*) uterus—(ovaries, vagina, and vulva);

(*k*) testicles;

(*l*) mammary gland — (supramammary lymph-nodes);

(*m*) feet;

(*n*) muscles — (routine incisions in accordance with the provisions of paragraph 9);

(*o*) fat, connective tissue, bones, joints, and tendon sheaths;

(*p*) carcass lymph-nodes — (routine inspection in accordance with the provisions of paragraph 9).

9. (1) *Cattle*—visual inspection of gums and palate; visual inspection, palpation, and incision of tongue (ventral aspect—root) which should be loosened but not detached; extensive incisions into the external and internal muscles of mastication, parallel to the lower jaw; visual inspection of heart after opening of pericardium—if necessary an incision into the heart muscle shall be made from the base to the apex (further incisions shall be made if *Cysticercus bovis* is suspected); visual inspection of oesophagus; visual inspection of the muscles exposed during splitting of carcass; the following routine inspection shall be made into each side: three incisions into the muscles of the shoulder proximal to the elbow joint, one incision into the adductor muscle of the hind-quarter parallel to the symphysis pelvis; any other incision or excision shall be permissible, without mutilation of the carcass, if the presence of *C. bovis* is suspected; the prescapular, external and internal iliac, supramammary, and renal lymph-nodes shall be incised; the stomach, intestines, and mesenteric lymph-nodes shall be viewed, the latter if necessary incised; the liver shall be visually inspected, palpated, and incised (an incision shall be made across the thin left lobe); the adrenal glands shall be examined by observation; the udder shall be incised and examined by observation and palpation; the outer surface of the uterus and the substance of the uterus and of the ovaries shall be examined—if considered necessary, the former shall be incised.

(2) *Calves*—in addition to the foregoing, the navel and joints shall be examined by observation and if necessary incised; the presence, consistency, and colour of the fat around the kidneys shall be noted; the skeletal muscles shall be viewed to ascertain their colour and consistency; visual inspection and if necessary incision of all parts known to be predilection sites for *C. bovis* regardless of age of calf; visual inspection of visceral surface of the liver.

(3) *Pigs*—the carcass shall be split before inspection ; the submaxillary and retropharyngeal lymph-nodes shall be exposed and incised ; lips and gums shall be viewed ; the tongue shall be detached from the head bones, palpated, viewed, and incised ; the pericardium shall be opened up and the heart visually inspected and incised by one cut stretching from the base to the apex ; the leaf fat shall be detached and the kidneys exposed (this may be omitted in export pigs for overseas) ; all exposed muscles shall be visually inspected, especially the neck, loin, and ham muscles as well as the fleshy part of the diaphragm ; the prescapular, iliac, superficial inguinal, and supramammary lymph-nodes shall be examined by palpation and if necessary incised ; the gastro-splenic and mesenteric lymph-nodes shall be incised ; incisions into the shoulder muscles may be omitted.

(4) *Sheep and goats*—the lips, gums, tongue, and nasal cavities shall be examined as practicable ; the prescapular, superficial inguinal, supramammary, and precrural lymph-nodes shall be examined in detail ; the lungs shall be viewed, palpated, and their basic lobes incised ; the liver shall be viewed, palpated, and an incision shall be made into the thickest portion of the organ or across the thin left lobe ; the mammary gland shall be examined by observation and palpation.

10. All carcass lymph-nodes and organs shall be examined in detail in carcasses marked " SUSPECT " during ante-mortem inspection and in carcasses derived from an emergency slaughter.

Diseases and Conditions affecting Fitness for Human Consumption

11. (1) No carcass derived from an animal judged " SUSPECT " during ante-mortem inspection or slaughtered in emergency shall be passed fit for human consumption unless it has been proved by bacteriological examination to be free from infection with food poisoning organisms, or if any of the following diseases or conditions have been established :

(*a*) sheep pox, erysipelas, swine fever ;

(*b*) bone fractures (without perforation of hide or skin) ;

(*c*) external injuries (without affecting the general health) ; foreign body in the oesophagus (without perforation) ; prolapse of the uterus, bladder, or rectum, provided slaughter has taken place immediately after the accident and no complication or fever was recorded.

(2) Carcasses from which samples have been taken for bacteriological examination shall be " RETAINED " under lock and key until a final decision can be reached.

12. The carcass and viscera shall be judged unfit for human consumption if affected with, or showing lesions of, any of the following diseases or conditions :

(i) Anthrax ;
(ii) Abscesses, multiple ;
(iii) Anaplasmosis and redwater [braxy], save where the carcass is in good condition ;
(iv) Actinomycosis and actinobacillosis, generalized ;
(v) Blackleg ;
(vi) Bluetongue ;
(vii) Cysticercosis, generalized ;
(viii) Caseous lymphadenitis, if the carcass is in poor condition or the lesions are either multiple, acute and actively progressive, or inactive but widespread ;
(ix) Decomposition, generalized ;
(x) Dropsy, generalized ;
(xi) Emaciation, pathological ;
(xii) Erysipelas, acute ;
(xiii) East Coast fever, save where the carcass is in good condition ;
(xiv) Foot-and-mouth disease ;
(xv) Heartwater, save if carcass in good condition and not feverish ;
(xvi) Immaturity, unborn or stillborn carcass ;
(xvii) Jaundice, if discoloration of the carcass is still present after 24 hours of cooling, or if the carcass is in poor condition, or dropsical, or if an unpleasant taste or smell is noted when carrying out the boiling or frying test ;
(xviii) Leptospirosis ;
(xix) Leukaemia ;
(xx) Mammitis, acute, septic ;
(xxi) Metritis, acute, septic ;
(xxii) Malignant catarrh ;
(xxiii) Nairobi sheep disease ;
(xxiv) Paratyphus of pigs ;
(xxv) Parturient paresis, carcass judged according to its merits ;
(xxvi) Pneumonia, acute, septic ;
(xxvii) Pleurisy, acute, diffuse, septic ;
(xxviii) Pericarditis, acute, septic ;
(xxix) Peritonitis, acute, diffuse, septic ;

(xxx) Pigment formation, generalized;
(xxxi) Polyarthritis;
(xxxii) Rabies;
(xxxiii) Rinderpest;
(xxxiv) Salmonellosis, generalized;
(xxxv) Sarcocystosis (*Sarcocystis miescheriana*), if the meat is watery and discoloured;
(xxxvi) Septicaemia and pyaemia;
(xxxvii) Tetanus;
(xxxviii) Transit fever, save when carcass is in good condition;
(xxxix) Trichinosis;
(xl) Trypanosomiasis, save where the carcass is in good condition and does not show lesions of fever and dropsy;
(xli) Tuberculosis, if the carcass is emaciated and/or fevered due to an acute blood infection, or if the lesions are generalized, extensive, or acute, or actively progressive;
(xlii) Tumours, generalized or malignant;
(xliii) Unpleasant odour or taste; or
(xliv) Swine fever.

13. Blood shall be considered unfit for human consumption:

(i) when the carcass and organs are condemned;
(ii) when the carcass and/or organs are found to be affected with any infectious disease;
(iii) when contaminated by stomach contents or other extraneous matter.

14. An organ or part of a carcass shall be unfit for human consumption if affected with, or showing lesions of, the following diseases or conditions:

(i) Tuberculosis:

(*a*) the head, including the tongue, shall be condemned if the retropharyngeal, parotid, and submaxillary lymph-nodes, or any two of these show lesions;

(*b*) the mesentery and associated part of the intestines shall be condemned if the mesenteric lymph-nodes alone show lesions;

(*c*) the trachea as well as the larynx shall be condemned if the lungs or associated lymph-nodes show lesions;

(*d*) if muscle lymph-nodes show lesions, all long bones in the respective drainage area shall be removed and opened up. If

a lesion is exposed, all skeletal bones shall be destroyed and the muscles sterilized, provided the carcass is in good condition; otherwise total condemnation of the carcass shall be enforced;

(*e*) in the absence of any symptoms of an acute blood infection, and if there are no lesions in the long bones, but muscle lymph-nodes show slight chronic lesions, the affected part only shall be sterilized;

(ii) Sarcocystosis (*S. miescheriana*):
the affected muscles only shall be condemned provided the infestation is localized and the meat normal;

(iii) Liver fluke, bladder worms, round worms, tapeworms, etc.:
provided that the affected part shall not be rejected when the lesions are slight and not numerous and the part is not changed in structure and appearance;

(iv) Abscesses, abrasions, bruises, injuries, tumours, etc.:
provided that the affected parts together with the surrounding tissues shall be removed if the lesions are localized or encapsulated and the regional lymph-nodes or the general system do not show any symptoms indicating spread or secondary infection;

(v) Pleuropneumonia:
the lungs and pleura shall be condemned;

(vi) Actinomycosis and actinobacillosis:
the affected parts and the corresponding lymph-nodes shall be condemned;

(vii) Inflammation:
the diseased part only shall be condemned if the area is small and localized and the regional lymph-nodes and/or general system not involved;

(viii) Malformations:
the affected parts shall be condemned;

(ix) Diamond skin lesions (skin erysipelas):
the affected part or the whole skin shall be stripped and condemned;

(x) Degeneration:
the affected organ or muscle shall be condemned;

(xi) Pigmentation, calcification, infiltration (haemorrhagic or watery):
the affected parts shall be condemned;

(xii) Decomposition (superficial), moulds (superficial), maggots, etc.:

the affected parts together with the surrounding tissues shall be condemned;

(xiii) Contamination (pus or inflammatory exudate):

the contaminated part together with the surrounding tissues shall be condemned;

(xiv) Arthritis:

the affected parts shall be condemned.

15. A carcass shall be deemed conditionally fit for human consumption if infested with *C. bovis* under the following conditions:

(*a*) any carcass showing 1-6 cysts or degenerated cysts shall be retained for 14 days at a temperature not above –10°C, or sterilized by heat in accordance with the provisions of paragraph 16, and then released unconditionally for sale on the market;

(*b*) any carcass of which the head or tongue, or thoracic or abdominal viscera, are infested with one or more active cysts shall be retained, and treated and released in accordance with sub-paragraph (*a*);

(*c*) any carcass showing 7-20 cysts shall be retained and treated in accordance with sub-paragraph (*a*), but released conditionally as " contract " meat only.

Treatment of Conditionally Fit Carcasses

16. Carcasses which have been declared conditionally fit shall be processed by either of the following methods:

(1) *Sterilization by heat treatment*—carried out by steaming, boiling or rendering:

(i) steaming—which entails heating by steam under moderate pressure (7 p.s.i. (0.49 kg/cm²)) in an autoclave for a period of not less than one hour;

(ii) boiling—which entails heating in a closed or open vat at a temperature of 76.6°C for a period of not less than 2½ hours;

(iii) rendering—which entails cooking of pork fat and tallow for a time sufficient to render them effectively into lard or tallow, provided all parts of the product are heated to a temperature not lower than 76.6°C for a period not less than 30 minutes.

Carcasses or parts subjected to heat treatment, preferably by steaming, shall be cut up into pieces not greater than 6 inches in thickness. The sterilization shall be regarded as adequate when the deeper portions of the meat have assumed a grey colour in the case of beef or a greyish-white colour in the case of pork, and where the muscle juice which exudes when the meat is cut has lost its reddish tint.

The heat treatment shall be carried out during regular hours of work under the direct supervision of an Inspecting Officer.

(2) *Freezing*—as a means of sterilization of carcasses affected with *C. bovis* shall be carried out in a cold-storage room, the temperature of which shall be maintained at a constant level of not more than –10°C for a period of at least fourteen days;

(i) before any carcass infested with *C. bovis* is placed in cold storage for sterilization, all obviously diseased parts shall be removed and a tag shall be securely affixed to each side;

(ii) a record of every carcass placed in cold storage for sterilization shall be kept;

(iii) the thermograph recordings of the temperature of a separate cold-storage room reserved for the sterilization of carcasses infested with *C. bovis* shall be preserved for a period of at least one month from the date on which such carcass was removed therefrom, and shall be available for inspection;

(iv) the cold-storage room in which carcasses infested with *C. bovis* are held shall be kept under lock and key and shall be under personal supervision of the Inspecting Officer in charge or his deputy.

17. Carcasses and parts declared conditionally fit for human consumption which have not been submitted to the treatment prescribed in paragraph 16 shall be regarded as unfit for human consumption.

18. Judgement and procedure in diseases and conditions not dealt with in this code shall be within the discretion of the Inspecting Officer.

Disposal

19. (1) Carcasses and parts judged unfit for human consumption shall be moved to the disposal-plant not later than 24 hours after judgement.

(2) Where a disposal-plant is not available, carcasses and parts unfit for human consumption shall be destroyed by burning.

Records

20. (1) Every Inspecting Officer shall keep a daily record book of slaughter and condemnation.

(2) In public abattoirs and meat production plants a record book shall be maintained in which shall be recorded daily all slaughterings and condemnations carried out on the premises. This record book shall be closed at the end of the calendar year and an annual report shall be made to the Director of Veterinary Services and the Director of Medical Services during the month of January.

(3) Daily record books and annual reports shall be kept for at least three years before being destroyed.

ANNEX 16

DISCUSSIONS AT WHO/FAO SEMINAR ON MEAT HYGIENE

Since many of the papers presented in this monograph served as a basis for discussion at the WHO/FAO Seminar on Meat Hygiene, held at Copenhagen from 22 to 27 February 1954, some of the opinions expressed and conclusions reached at the Seminar are outlined below.

Epidemiology

The fundamental problem of terminology was touched upon by several speakers, the need for making a definite distinction between the terms " food-borne infection " and " food poisoning " being particularly stressed. It was thought that the first term should be used to designate all infections caused by the presence in food of a pathogenic organism which, through consumption of the food, is transmitted to the host—man—where it can multiply and invade the tissues ; whereas the second should be reserved for cases of illness caused by consumption of food containing some toxic compound either of physical or of bacterial character. The bacterial toxins are of two types—exotoxins, or true toxins, and endotoxins. They can be further classified according to their mode of action as neurotoxic (e.g., *Clostridium botulinum*) and enterotoxic (e.g., *Staphylococcus* sp., *Bacillus cereus*, and *Cl. perfringens*).

Since a low carrier-rate was found among slaughter animals examined after the start of the 1953 epidemic of salmonellosis in Sweden (see page 40), the question was raised whether this outbreak had been caused by intravital infection of slaughter animals or by post-mortem contamination from some source. It was pointed out that intravital *Salmonella* infection of slaughter animals was quite common in several parts of the world, an example being given of approximately 400 cases of gastro-enteritis which were shown to have arisen from the consumption of meat from a single intravitally infected animal. In the Swedish outbreak, however, post-mortem contamination appeared to be the more logical explanation.

The fact that outbreaks of meat-borne disease are seldom reported is no guarantee of a country's immunity from this potentially dangerous threat. Prior to the 1953 outbreak, salmonellosis had occurred sporadically in Sweden, but the population generally had little experience of this type of infection. It was only when the public-health services were faced with an explosive outbreak, threatening a large section of the community, that the

need was appreciated for extensive study of all the factors involved—agent, host, and environment—in order to determine the cause of the disease and to take steps to check its spread. It was emphasized, therefore, that those countries which seem to be relatively free must not overlook the fact that meat-borne infections probably do occur and that thorough investigation in suspicious cases of illness would undoubtedly bring them to light.

With regard to outbreaks of food poisoning caused by bacterial toxins, it was stated that staphylococci were considered to play the most important role in the USA, *Cl. perfringens* was reported to be an important agent in Sweden and Denmark. *B. cereus* was also known to have caused poisoning in meat products, especially those whose ingredients included flour, in particular potato flour.

There was general agreement that many cases of food-borne disease were due to bad handling of food in households and shops, and that the problem of the prevention of meat-borne diseases was a matter for consideration and co-operation by many disciplines. Indeed, it was felt that without team-work among public-health officers, epidemiologists, veterinarians, sanitary engineers, public-health educators, and private physicians, no fruitful results could be obtained.

Ante-mortem care

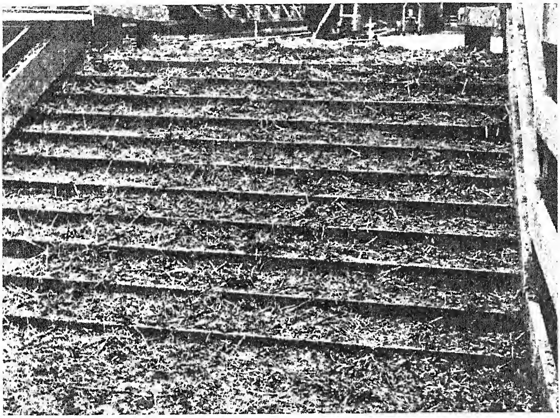
It was generally agreed that ante-mortem inspection was fundamental to any safe system of meat control and that the veterinarian must play the major role in this inspection, since it requires special clinical knowledge and training.

Some objection was raised to permitting the introduction into abattoirs of animals already dead from causes other than slaughter.

It was pointed out that, apart from the fact that humanitarian dictates require periods of rest, watering, and feeding to be provided where long-distance transportation of animals by rail or road is involved, such measures considerably reduce losses from disease, exhaustion, and other causes. Sanitary and construction specifications for ship, rail, and road conveyances are therefore of great importance, in addition to veterinary supervision while the animals are *en route*.

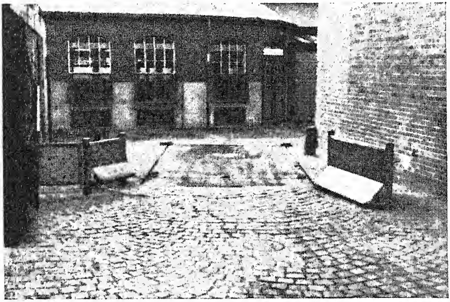
Attention was drawn to new types of ramp designed to prevent injury and damage when loading and unloading slaughter animals. In particular, a ramp (see Fig. 1) constructed of cement steps, widely spaced and lipped by angle irons, has proved to be of considerable value in lessening damage. Another, and possibly better, solution is a kind of weighbridge on to which the lorry is driven and then mechanically lowered until its floor is on a level with the ground (see Fig. 2, 3).

FIG. 1. MODERN TYPE OF UNLOADING RAMP IN USE IN CHICAGO STOCK-YARDS



Kindly provided by Dr H. Thornton, Chief Veterinary Officer, City and County of Newcastle-upon-Tyne, England

FIG. 2. WEIGHBRIDGE FOR UNLOADING ANIMALS



Kindly provided by Dr V. E. Albertsen, Danish Veterinary Service, Department of Meat Hygiene, Copenhagen

FIG. 3. WEIGHBRIDGE UNLOADING PIGS

Kindly provided by Dr V. E. Albertsen, Danish Veterinary Service, Department of Meat Hygiene, Copenhagen

Finally, great stress was placed on the necessity for giving the animals an adequate period of rest after shipment and before slaughter. The rest period gives the opportunity for careful ante-mortem inspection to detect sick animals, and ensures more adequate bleeding and, consequently, meat of better keeping quality.

Slaughter

On the question of slaughterhouses, it was pointed out that great efforts had been made, especially after the Second World War, to improve slaughterhouse premises in different European countries.

There was general agreement on the necessity for providing separate bleeding-compartments, even in smaller slaughterhouses not provided with overhead bleeding-rails, in order to prevent possible pollution of the flooring from the blood. In that same connexion, attention was drawn to the need for separating clean and unclean slaughter operations, as regards both premises and personnel. (Some suggested designs for abattoirs are given in Annex 6, page 383.)

Attention was also called to the great value of a rapid cooling system which has proved satisfactory in the more temperate parts of Europe and which has both hygienic and economic advantages. Immediately upon slaughter, the carcasses are transferred into refrigeration tunnels with a high-speed air current, the temperature of which is kept at an even 2°C

(35.6°F) and the relative humidity at 90%-95% (see Fig. 4, 5). Use of this technique saves post-slaughter loss of weight in the meat and prevents the multiplication of any bacteria that may be present in the carcasses.

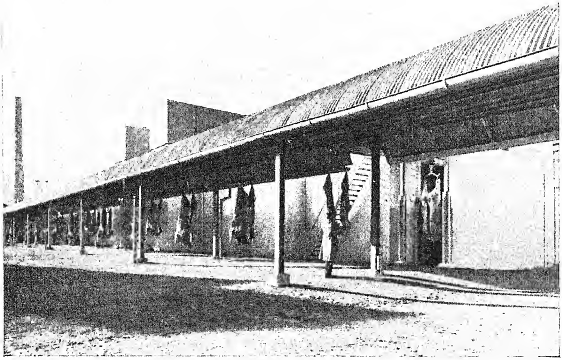
Several speakers were entirely in favour of the use of stainless steel instead of wood for slaughterhouse equipment. Although expensive, this material is durable and easily disinfected.

Attention was focused on the importance of the increased use of bacteriological examinations in the slaughterhouse, not only in order to detect bacterial pollution during the different operations, but to check other sources of infection as well, for example, in connexion with *Salmonella* transmission through animal carriers.

It was pointed out that rendering-plants for condemned carcasses and other wastes should be located away from slaughterhouses, preferably in the countryside.

There was no general agreement on the question of separating the administration of municipal slaughterhouses into technical management and sanitary management ; the contrary view advocating single control by

FIG. 4. CARCASSES TRAVELLING ON CHAIN PULLEY FROM SLAUGHTERING-HALLS TO COOLING-TUNNELS

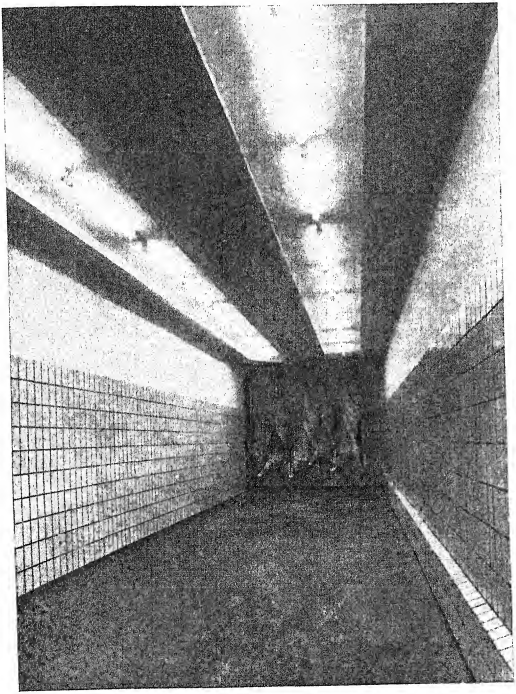


Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

one person, who should preferably be a veterinarian with special training and experience in all branches of meat hygiene and meat inspection, was also upheld.

As to methods of stunning and slaughter, two systems of electrical stunning were described : one in which the electric shock is introduced by

FIG. 5. INTERIOR OF COOLING-TUNNEL



Kindly provided by Dr M. J. J. Houthuis, Director, Municipal Slaughterhouse, Rotterdam, Netherlands

applying a high-tension current (150-300 volts) for a short space of time ($\frac{1}{2}$-$1\frac{1}{2}$ seconds) and one in which a low-tension current of about 70-80 volts is applied for 10-15 seconds ; the former is suitable for cattle and the latter is more particularly used for pigs.

The question was raised of whether or not complete anaesthesia really results from electrical stunning. The general opinion was that complete and true anaesthesia is produced, provided the electrodes are properly placed.

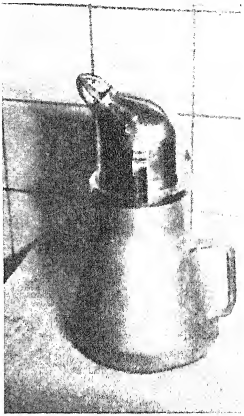
In Denmark, where about 4 000 000 pigs are slaughtered annually and large economic interests are vested in the bacon industry, careful consideration has been given to the question of whether or not the electrical method of stunning would have an adverse influence on the bleeding and keeping qualities of the meat, particularly of bacon. Bacteriological examinations and experiments to evaluate the quality of meat under refrigeration and after pickling have, however, shown no obstacle which could be attributed to the use of this method. Even though the different methods used for estimating the amount of blood found in slaughtered carcasses were not altogether satisfactory, the general finding was that bleeding after electric shock is just as complete as bleeding without stunning. With regard to muscle haemorrhage, especially in the iliopsoas muscle, experiments have shown that this reaction is as frequent in pigs killed without previous stunning as in those electrically stunned.

The sole effect that might cause difficulty is the occurrence of haemorrhages in the lungs of electrically stunned pigs. While of no great consequence in themselves, these haemorrhages might cause confusion in countries where swine fever (hog cholera) is prevalent, as, for example, the USA, because they could be mistaken for evidence of this disease or of septicaemia, and thus make meat inspection difficult. Hence, it was considered important to keep the voltage, which might otherwise be responsible for lung " splashing ", within certain limits (70-80 volts).

As regards danger to human beings, the balance of opinion in Denmark was that, provided the installations are in perfect condition, the locality well insulated, and the voltage kept down to 70-80 volts, no risk to humans is involved. The electrical method of pig stunning was considered the most practical available at the present time for use in a mechanized plant operating at high speed.

A new method of pig stunning by inhalation of carbon dioxide gas, which is now in use in the USA, was also described. The pigs are transported by a conveyor-belt through a tunnel where they inhale a high concentration of CO_2 gas (60%-75%) for 45-50 seconds ; in about 15 seconds they become unconscious, and remain insensible for about 55 seconds after emerging from the tunnel. Experience of this method in the USA has been

FIG. 6. DANISH CONTAINER FOR BLOOD COLLECTION



Kindly provided by Dr V. E. Albertsen, Veterinary Officer, Danish Veterinary Service, Department of Meat Hygiene, Copenhagen, Denmark

that the bleeding is good and a 40% saving in labour costs for shackling and bleeding has been recorded. The inhalation of CO_2 gas has no harmful effects so far as human food-consumption is concerned, since CO_2 dissociates itself from the blood as soon as the pig begins to breathe in fresh air.

It was the general opinion that stunning of animals prior to slaughter was highly desirable and should be practised wherever possible.

The vacuum-tube system for the collection of blood to be used for human consumption, as described by Dr. T. Blom (see page 144), was regarded by a number of speakers as over-complicated and, hence, too difficult to keep clean and bacteriologically sound. Preference was expressed for less complex methods, and a simple container of the type used in Denmark for the collection of pigs' blood was demonstrated. This apparatus is easy to handle and to keep in a hygienic condition ; moreover, it precludes contamination from without (see Fig. 6, 7).

In regard to the contamination of pigs' lungs by dirty water from scalding, it was pointed out that this is easily preventable by the use of forceps on the trachea or by plugging the throat, both of which methods were in use in Denmark.

Post-mortem inspection

It was stressed that general principles for the judgement of meat should be so framed as not only to eliminate danger to human health but also to cover any factors that might render meat unacceptable as human food by general cultural standards and local practice. In addition, it is essential to have a guaranteed standard of general freshness and hygienic quality. To fulfil these requirements, it is necessary to condemn meat that is :

(*a*) actually or potentially dangerous to health through the possibility of transmitting parasitic diseases or causing food-borne infections ;

FIG. 7. DANISH CONTAINER FOR BLOOD COLLECTION IN USE

Kindly provided by Dr V. E. Albertsen, Veterinary Officer, Danish Veterinary Service, Department of Meat Hygiene, Copenhagen, Denmark

(*b*) so deteriorated in appearance, taste, and texture as to render it unacceptable by local standards ;

(*c*) contaminated or polluted through contact or admixture with unappetizing or objectionable material ;

(*d*) of a keeping quality considerably below the normally accepted standard for its kind.

It was generally recommended that any slaughterhouse of importance should have its own laboratory, so that bacteriological and biochemical tests could be applied immediately in any suspected case.

Some discussion took place on the use of rapid tests during meat inspection, such as simple tests to demonstrate incomplete bleeding and to determine the water content and the pH of the meat, as well as application of the boiling and frying tests commonly used for detecting abnormal odouis. Such simple tests could be carried out in any slaughterhouse, since they do not require elaborate laboratory facilities.

There was some disagreement with the view that palpation of the superficial lymph-nodes is valueless; it is relied upon in many countries, especially in the case of mutton and lamb in areas where caseous lymph-adenitis is common.

It was also pointed out that the examination of the gall-bladder for thickening of the walls should be included in the post-mortem inspection; this is a matter of great importance to countries with a high incidence of *Salmonella* carriers in animals. In regard to the examination of the thoracic cavity and the submaxillary lymph-nodes, a kind of tip-trestle, as installed in Danish bacon factories, was demonstrated (see page 186). It is easy to handle and facilitates the examination of carcasses which are still hanging.

Two opposing viewpoints emerged from the discussion on a possible international code for the judgement of meat, the one favouring the drawing-up of a rigid examination and judgement code, leaving as little as possible to the discretion of the meat inspector, and the other holding that there was no need for a set of rigid rules and that final judgement should be left to qualified veterinarians. The final balance of opinion was that any international code of instructions must clearly take into account the varying customs and practices in the different countries, and that the best solution would be a middle course—namely, a set of recommendations, leaving the rest to the inspector's own discretion.

The judgement of tuberculous carcasses should be based not only upon an inspection of the site of lesions, but more specifically upon an evaluation of their nature. Tuberculous carcasses can safely be passed for human consumption only in cases of healed primary infections or where chronic tuberculosis is limited to certain organs that can be excised and discarded. It was agreed that the use of sterilized meat from tuberculous carcasses for human food is justifiable on economic grounds.

The presence of tubercle bacilli in the muscular tissues is apparently more common than was originally thought to be the case, and this is therefore a matter requiring further study.

The lack of statistics showing the incidence of meat-borne tuberculous diseases in man was another matter that came up for discussion. The direct contamination of man through milk from tuberculous cattle is already amply proven, but this proof has been easier to obtain owing to

the fact that children are large consumers of milk at an age before they have acquired "immunity" against tuberculosis. In the older age-groups of the population, where meat figures more largely in the diet, specific sources of infection are less easily traceable. Undoubtedly, meat as well as milk can cause tuberculosis in man, but reliable proof of the relative part played by the former in this infective process is still lacking. Research aimed at compiling the requisite statistics would be the only way to establish the incidence of infection from this source.

The economic factor looms large in the judgement of meat from tuberculous animals. Leniency is the general rule wherever fresh meat for human consumption is scarce. On the other hand, judgements tend to be much stricter in countries where meat supplies are fairly adequate and the meat-inspection service is of a relatively high standard. The general view taken was that stringent judgements are applicable in countries allowing the sale of sterilized meat from tuberculous carcasses, since meat passed for conditional sale in this way still has an appreciable value.

In the discussion regarding parasite-infested carcasses, attention was focused on the three following diseases: hydatidosis, cysticercosis, and trichinosis.

Hydatidosis has shown an increase in many countries. It is dangerous to man, often causing death when it attacks the liver, lungs, or brain. Preventive measures against this disease should include campaigns directed towards ensuring the complete destruction of all infested organs detected in slaughter animals in the slaughterhouse. In infected areas regular treatment of all dogs by vermifuge together with destruction of their faeces should be compulsory. Concurrently with these measures, education of the public, accompanied by instruction in hygiene, especially directed to butchers, shepherds, and dog-owners, is necessary. In 1943 these measures reduced the incidence of this disease among animals in the province of Friesland, Netherlands, from 16% to 2%.

The situation with regard to *Cysticercus bovis* is particularly alarming, since cysticercosis is definitely increasing in many countries despite advanced meat-inspection techniques.

Statistics from several countries show that human tapeworm-carriers are more prevalent in cities than in rural areas, probably because consumption of raw meat or meat products is commoner in the former. The main problem is how to prevent the parasite's being carried from town to country. In Europe, the chief source of parasitic eggs is faecal-polluted sewage from the cities. How to stop this sewage from reaching streams and rivers frequented by cattle is the difficulty. A method of sand filtration of sewage widely used in the Union of South Africa is easy to operate and gives reasonable, though not complete, safety. In Denmark, an additional

factor has been the transmission of tapeworms by seagulls, which are known to feed in sewage-disposal plants and to frequent pastures in coastal and inland areas.

The higher frequency of tapeworms in the female sex was attributed to the fact that housewives are apt in the preparation of meals to taste the meat for seasoning purposes before it is thoroughly cooked.

It was recognized that meat inspection is often carried out without adequate regard to the predilection sites of *C. bovis*. Danish experiments on calves fed on sewage-polluted pastures have demonstrated that, whereas the routine examination of these sites showed a very low percentage of "measles", a more thorough examination of all the muscles brought to light the presence of infection.

Nevertheless, no new proposals were put forward for amplifying the inspection procedure, beyond a suggestion to include the oesophagus in the routine examination, although the opinion was generally held that present-day inspection techniques not infrequently miss light *Cysticercus* infection in cattle. Nor was any increase recommended in the normal number of inspection cuts made for detecting the parasite. In countries where cysticercosis is prevalent and this technique is not as yet in use, it might be of value to introduce it.

It was finally suggested that public-health services, besides organizing campaigns against the consumption of uncooked meat, should try to improve their techniques for tracing human tapeworm-carriers. A recently developed method was described, in which cellophane tape is applied to the skin of the anal region so that any eggs will adhere to it, and is then placed on a glass slide with a drop of oil for microscopic examination. This method is not only simpler and less troublesome, but has proved considerably more efficacious than the more usual practices. In one instance it increased the detection of carriers from 2% to 19%. The method is recognized in Denmark and has been recommended to the medical profession for incorporation in the routine clinic and hospital examinations.

As regards trichinosis, the general consensus in the seminar seemed to be in favour of using the trichinoscopic examination of meat to a larger extent. It was realized that the method is not ideal and will not detect every case, but it is still better than none at all. One great advantage is that it not only excludes the most dangerous meat from consumption, but also enables localized centres of infection to be detected and attempts made to eradicate the disease in specific areas.

Attention was also drawn to the need for regulations covering the feeding of raw garbage to pigs, and to methods of destroying trichinae in

meat by freezing, heating, and other means. It was felt that such procedures should be compulsory in countries where trichinosis is prevalent.

Coming to the question of bacteriological and biochemical testing as aids to the judgement of meat, the essential features of a laboratory examination were considered to be speed, simplicity, and efficiency.

The samples selected for the bacteriological examination of slaughter animals should be confined to sections open to infection through the blood-stream, e.g., lymph-nodes, spleen, and muscular tissue. The possibility of using bone-marrow was also considered.

Transportation of samples to laboratories constitutes a problem. A method was described whereby the surface of the sample is sterilized in boiling paraffin and the whole transported in a solid block of paraffin, thus eliminating the risk of contamination. Swedish experiments have clearly demonstrated that non-pathogenic bacteria are more often found in samples sent by post than in those examined in a slaughterhouse laboratory. Denmark has tried to solve the problem by decentralizing laboratory organization and encouraging the establishment of laboratories as close as possible to the sites of slaughterhouses.

With regard to the relative importance of bacteriological findings in the different samples, the general view was that where pathogenic bacteria are found a carcass should be condemned, irrespective of the location of the infection.

On the question of media for *Salmonella* identification, attention was drawn to the use of tetrathionate broth followed by subcultures in desoxycholate medium, which was much favoured in the USA.

It was emphasized that the application of laboratory tests and laboratory diagnosis should not be overdone. Bacteriological examination is not justified in all cases and some selection has to be made. Apart from compulsory examination under certain established criteria, it should be left to the meat inspector to select other cases where laboratory examination may prove helpful, and it must never be forgotten that it is the trained meat inspector who is ultimately responsible for classifying the meat.

As regards the application of laboratory methods in the control of meat and meat products outside the slaughterhouse, it was emphasized that as yet samples taken from the market or the factory are usually subjected to chemical quantitative analysis only. In that connexion, the need for close co-operation between bacteriological and biological laboratories and the field inspecting staff was stressed. Inspection of a product by the naked eye and verification of cleanliness are not enough; clearly, further examination from the standpoint of hygiene is essential since, otherwise, the controlling authorities are left completely ignorant of the hygienic

quality of the foodstuff and are incapable of passing correct direct judgement on suspected consignments. Each country must work out for itself the bacteriological hygiene standards for the meat products it produces.

As regards the organization of laboratory services, the balance of opinion was that large slaughterhouses and processing plants should have their own laboratories, and that, in addition, a number of larger laboratories, with better equipment, are needed to carry out more difficult testing. Hence, a combination of small local and larger regional laboratories would be an ideal arrangement.

Processing and marketing

It was emphasized that the hygienic control of meat in markets and in food-serving establishments is probably the most difficult problem in the whole field of meat control, because the influence of the human element is so very great. Successful control here would, however, greatly contribute towards diminishing the risk of food-borne disease.

Opinions differed as to the degree to which control should be exercised over the health of food-handlers and food-processing employees. It was agreed that, as a minimum, certain groups, in particular staff employed in hospitals, child clinics, school kitchens, etc., should be examined regularly for detection of carriers of pathogenic organisms, but at the same time the great difficulties that would beset any attempt to institute regular medical examination of food-handling staff in canteens, restaurants, and shops were fully appreciated. A single examination (at the time of engaging staff, for instance) is not sufficient to detect a carrier and, as is well known, large groups of people are opposed to bacteriological examinations of the kind needed for this purpose.

There was more general agreement on the value of educational work among the public and especially among groups involved in food-handling. Good results have been achieved in the USA by giving a short series of lectures to varying groups of people, in order to impress upon them the need for simple hygienic procedures. Stress was laid, too, on the importance of immediate reporting of any occurrence of illness of any type whatsoever in a person handling food, and proprietors of food shops should be urged, it was felt, to exclude any such workers during the period of illness.

It is important to remember that food should always be kept under conditions that will prevent the incubation of any bacteria that may be present. As temperatures of between 15°C and 50°C (59°F and 122°F) tend to increase bacterial growth, food ought never to be kept for any length of time at such temperatures.

Attention was drawn to the current practice in some countries of placing meat and meat products on sale, ready cut into slices and joints

and wrapped in cellophane paper. This is a procedure requiring extra precautions and what amounts to a surgical standard of cleanliness, as well as adequate subsequent refrigeration, because the meat surface open to contamination is increased and the higher humidity inside the wrapping favours bacterial growth.

On the question of sterilization of cold chambers, there was no general agreement regarding the effectiveness of ultra-violet rays. Ultra-violet rays, some held, can reduce atmospheric contamination but are not effective for the sterilization of carcass surfaces, because their range of penetration is too restricted, thus limiting the possibilities of wholesale destruction of any bacteria present. The question has been investigated from the practical angle in Denmark, but the results have not proved encouraging. The importance of having the lamp placed near the object to be sterilized was pointed out, but this did not alter the general opinion that the matter required further experiment and elucidation.

It was again strongly stressed that each step in the treatment of meat is one link in a chain stretching from the farm to the consumer's doorstep. Everything that happens to the animal while alive and in transit has an effect, good or bad, on the meat and on the processed product. Meat hygiene, therefore, must be one continuous operation and not a mere series of disconnected actions carried out at the different stages.

Training of personnel

Training in meat inspection should be given by veterinary surgeons with sound practical and theoretical knowledge. In many countries the time allowed in curricula for meat and milk hygiene is insufficient to justify the appointment of a full-time professor, with the result that the subject is not always properly taught.

Practical experience in abattoirs is an important part of the training, but the theoretical background is also essential and should not be neglected. Students must have a firm grounding, with particular emphasis on anatomy, physiology, pathology, and bacteriology.

One important problem concerns the kind of personnel best suited to train for meat inspection. Three existing systems were described:

(1) meat inspection by qualified veterinarians only;

(2) inspection by specially trained, so-called "lay" inspectors, working under the supervision of veterinarians; and

(3) inspection by sanitary inspectors working under medical officers of health.

It was realized, however, that there is a shortage of veterinarians in many countries; so that even if a system operated exclusively by qualified

veterinary staff may be considered the ideal, many areas of the world will have to rely on lay inspectors, working under the guidance and supervision of graduate veterinarians, if there is to be any meat inspection at all.

With regard to the general organization of a meat-control service, two existing systems were described:

(*a*) A system in which the administrative and executive functions of meat-control and meat-hygiene supervision are incorporated in the general food-control service. The examination of animals and meat in slaughterhouses is the responsibility of the veterinary service of the ministry of agriculture, the supervision of slaughterhouse sanitation being the function of sanitary inspectors working under the authority of the ministry of health. The examination of meat put on the market remains the function of the veterinary service in so far as pathological conditions are concerned. However, after the meat has been transformed into manufactured meat products, control lies in the hands of sanitary inspectors and food bacteriologists of the general food-control service. The supervision of meat-processing establishments still remains in the hands of the ministry of health, whose medical officers exercise a variety of functions. Briefly, the entire field of meat hygiene has been divided according to functions and topographical features between a variety of professional groups and administrative authorities working in collaboration.

(*b*) A system of a specialized nature, in which meat is considered as meat, whether in the slaughterhouse or in the form of a manufactured product, and the entire field of meat hygiene has developed into a specialized branch of food control handled by one professional group under a single administrative authority. In some countries a dual meat and milk control organization has been set up as a specialized branch within the general food-control system, based upon separate legislation and a separate administration.

It was generally agreed that the system of organization spreading the responsibilities among different authorities would be liable to result in a disjointed coverage of meat hygiene. A gap in activities could arise and the result would be inefficiency. The different functions of meat control from producer to consumer ought to be unified under the responsibility of one professional group, acting as the main executive body. Help on specific problems can always be requested from other professional groups if the need arises.

Food hygiene is primarily the concern of ministries of health, and since it was recognized that many aspects of food hygiene should be under veterinary inspection, it may be possible to organize a public-health veterinary section, which should be responsible for the control of all food products of animal origin. Such a system has worked satisfactorily in a

number of countries. It has proved efficient and maintains the broad lines of control within one uniform organization.

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